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Is the Latin American and Caribbean capital stock affecting the development of the region? An analysis of capital stock's effects on the region's growth, inequality, and energy intensity

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Tese para obtenção do Grau de Doutor em
Economia
(3º ciclo de estudos)

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Dedicatória

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Preface

Since the presentation and publication of my master's thesis[1], the Latin America and the Caribbean region has always been the core sample of my investigations. The main reason for this fact is that, as it is known, although this region has enormous growth potential, it suffers from several problems which undermine its sustainable development (e.g. political instability, high levels of corruption and inequality, great dependence on the exploitation and export of natural resources, among others).

Due to the recognised region's growth potential, it is of special interest that researchers pay a considerable amount of attention to the study of the region's problems and their subsequent effects on the region's economies. In the end, this will allow contributions to the regional policy makers on the development of appropriate growth and development policies for this region.

In the case of this doctoral thesis, it was focused on the study of the effects that one specific problem may have had on Latin America and Caribbean development, with this problem being its lack of physical capital. This negative particularity and the constraints that it can bring to this region have already been cited by some previous researchers, as also by some important international institutions (as the International Monetary Fund).

Although the idea that higher physical capital investment is needed in this region be almost consensual, the studies focused on this thematic are still scarce. Thus, given that the region will probably need to make an investment effort in the near future, it becomes increasingly critical to evaluate how physical capital has materialised itself in these economies as also to evaluate its effects on the region's development. This way, it will be possible to help the region's governments on the development of their future physical capital investment projects so that they can be channelled to this region's economic, social and sustainable development.

In order to achieve this objective, four main essays were developed in this thesis. As it could be expected, this thesis has experienced several phases of maturation until

[1] Santiago, R., Fuinhas, J. A., and Marques, A. C. (2020). The impact of globalization and economic freedom on economic growth: the case of the Latin America and Caribbean countries. Economic Change and Restructuring, 53, 61–85. https://doi.org/10.1007/s10644-018-9239-4.

reaching its final form, giving rise, during its development process, to a series of outputs which will be presented below.

First, in Chapter 2, a historical analysis of the evolution of both public and private capital stocks and investments in the Latin America and the Caribbean region was developed from 1970 until 2017. This analysis made it possible to verify if the hypothesis that the region suffers from a lack of physical capital was indeed true. Moreover, an extensively adapted version of this analysis is also included in the first chapter of the book entitled "Physical Capital Development and Energy Transition in Latin America and the Caribbean" (ISBN: 978-0128244296), which is set to be published in 1st August 2021 by the Elsevier.

After verifying the veracity of this hypothesis, the relationship between the public capital stock, the private capital stock, and the economic growth in this region was then addressed in Chapter 3. Parts of this investigation were presented at an international conference and gave origin to a journal article publication:

- Santiago, R., Koengkan, M., Fuinhas, J. A., and Marques, A. C. The relationship between public capital stock, private capital stock, and economic growth in Latin America and Caribbean countries, XXI International Congress of the Word Economy Society/Sociedad de Economía Mundial, Covilhã, Portugal, 12-14 June 2019.[2]
- Santiago, R., Koengkan, M., Fuinhas, J. A., and Marques, A. C. (2019). The relationship between public capital stock, private capital stock and economic growth in the Latin American and Caribbean countries. International Review of Economics, 67, 293–317. https://doi.org/10.1007/s12232-019-00340-x.

After the investigation of the previous relationship, the impacts of both types of capital stock on income inequality (one of the most worrisome regional problems) were then investigated. Parts of this investigation were included in Chapter 4 of this thesis, being presented at an international conference and being currently under review process in the "Latin American Economic Review" journal:

- Santiago, R., Fuinhas, J. A., Marques, A. C., and Koengkan, M. What effect does public and private capital have on income inequality? The case of the Latin

[2] 2nd place in XII "JOSÉ LUIS SAMPEDRO" Award from the WES-World Economy Society/SEM-Sociedade Mundial Economia.

America and Caribbean region, ICABM2020 - International Conference on Applied Business and Management, Oporto, Portugal, 25-26 June 2020.

Finally, the role of public and private capital stock on the Latin American and Caribbean energy intensity was investigated in Chapter 5. This investigation gave origin to a journal article publication:

- Santiago, R., Fuinhas, J. A., and Marques, A. C. (2020). An analysis of the energy intensity of Latin American and Caribbean countries: Empirical evidence on the role of public and private capital stock. Energy, 211, 118925. https://doi.org/10.1016/j.energy.2020.118925.

It is also important to stress that full modified versions from the Chapter 3, Chapter 4, and Chapter 5 of this thesis are also included in the "Physical Capital Development and Energy Transition in Latin America and the Caribbean" book from Elsevier (ISBN: 978-0128244296), specifically in the second, third and fourth chapters of this same book.

In the end, it is expected that the research conducted in the thesis, and the outputs that were produced, be taken into account by the people in decision-making positions in this region so that they can help them to construct suitable physical capital investment strategies centred on the promotion of the Latin America and the Caribbean development.

Finally, it is also important to recognise the significant contributions from the thesis advisor (supervision, validation, data curation, writing - reviewing and editing) and co-advisor (visualisation and formal analysis) to this research, as also to all who were present at the conferences and to the unknown reviewers that carefully evaluated the papers that were submitted for publication. Moreover, this research also benefited from Dr Matheus Koengkan's expertise in the Latin America and Caribbean region.

Resumo

Segundo as conclusões dos relatórios de várias instituições internacionais, como o Fundo Monetário Internacional, a região da América Latina e Caraíbas tem vindo a sofrer de uma falta de investimento em capital físico nas últimas décadas. Facto que se verifica principalmente se olharmos tanto para os níveis como para o estado das suas infraestruturas. Como seria de esperar, esta não é de todo uma situação desejável, principalmente porque, de acordo com os mesmos relatórios, pode dar origem a vários efeitos nefastos nas economias desta região. Posto isto, é natural que cada vez sejam menos as dúvidas relativamente ao facto de que para promover o desenvolvimento da região da América Latina e Caraíbas, esta terá, num futuro próximo, de ser capaz de aumentar os seus níveis de capital físico.

Tendo em conta os factos enunciados anteriormente, nesta tese elaborámos vários ensaios com o intuito de: 1) avaliar os impactos do capital físico no desenvolvimento da região; 2) ajudar os decisores políticos regionais na elaboração das suas futuras estratégias de investimento. Para atingir estes objetivos, tirámos partido dos dados que foram recentemente disponibilizados pelo Fundo Monetário Internacional relativos ao capital público e privado da região. Inicialmente a nossa ideia seria apenas utilizar os dados referentes ao *stock* de capital público, pois é aquele que está ligado à provisão de infraestruturas económicas e sociais pelos governos, no entanto, como os dados para o *stock* de capital privado também se encontravam disponíveis, decidimos também incluir esta variável na nossa análise. Porquê *stocks*? Porque desta forma ao invés de apenas contarmos com os fluxos anuais de investimento público e privado (apenas os acréscimos de capital), contamos com o volume de capital existente na realidade, bem como com os efeitos da depreciação.

Podemos começar por referir que o primeiro ensaio se prendeu com a análise histórica da evolução de ambos os tipos de capital na região da América Latina e Caraíbas desde 1970 até 2017, por forma a poder verificar se existiu de facto uma falta de investimento em capital físico nesta região. Recorrendo aos dados do Fundo Monetário Internacional, foram elaborados gráficos referentes ao progresso do investimento e dos *stocks* nesta região durante o período temporal previamente enunciado, acompanhando esta análise com, passe a redundância, a análise da conjuntura económica da região e com comparações com a evolução do capital físico em regiões similares à América Latina e Caraíbas. Os resultados desta análise parecem apontar para a veracidade da hipótese de

que a região sofre de uma falta de investimento em capital físico, sendo a região da América Latina e Caraíbas caracterizada por um nível relativamente baixo de investimento público (principalmente quando comparada com regiões semelhantes), por um investimento privado muito volátil e por uma evolução muito lenta (em alguns períodos quase constante) dos seus *stocks* de capital público e privado em percentagem do produto interno bruto (PIB).

Depois desta análise mais descritiva, os três ensaios que se seguiram basearam-se em análises empíricas aplicadas a painéis de países da América Latina e Caraíbas, no sentido de estudar os efeitos de ambos os *stocks* de capital no crescimento económico da região, nos níveis de desigualdade de rendimentos da região e na intensidade energética da região, respetivamente. Desta maneira pudemos avaliar as contribuições que os stocks de capital público e privado tiveram em vários campos do desenvolvimento, nomeadamente nos campos económico, socioeconómico e sustentável.

Relativamente às metodologias utilizadas, no segundo ensaio desta tese, onde investigámos a relação entre os *stocks* de capital e crescimento económico, utilizámos a metodologia *panel vector autoregressive* (PVAR), para estudar os impactos de curto prazo e causalidades de *Granger*, e os estimadores *panel dynamic ordinary least squares* (PDOLS) e *panel fully modified ordinary least squares* (PFMOLS), para estudar os impactos de longo prazo. No terceiro, onde estudámos os impactos de ambos os *stocks* de capital na desigualdade de rendimentos, utilizámos o modelo *panel autoregressive distributed lag* (PARDL) e o estimador *Driscoll-Kraay* (DK) com efeitos fixos (efetuando ainda uma correção dos modelos para os efeitos dos choques), para estudar os impactos de curto e de longo prazo. Por fim, no quarto, onde estudámos o papel do *stock* de capital público e do *stock* de capital privado na intensidade energética da região, utilizámos o modelo *panel autoregressive distributed lag* (PARDL) e o estimador *Driscoll-Kraay* (DK) com efeitos fixos, para estudar os impactos de curto e de longo prazo, o método *log t regression test* e o *club clustering algorithm*, para investigar os vários clubes de convergência em termos de intensidade energética, e o modelo *ordered-logit*, para verificar se os *stocks* de capital seriam determinantes na formação dos clubes.

Os resultados dos ensaios presentes nesta tese parecem indicar que: 1) tanto o capital público quanto o privado tiveram um efeito positivo no crescimento económico de longo prazo dos países da América Latina e Caraíbas; 2) no curto prazo, o capital público parece ter produzido efeitos negativos tanto no crescimento como no capital privado (efeito *crowd-out*); 3) o *stock* de capital (público, privado e total) parece ter contribuído para o aumento da desigualdade de rendimentos no curto prazo; 4) no longo prazo, esse efeito

parece desaparecer (o que continua a não demonstrar uma contribuição do capital físico para a redução da desigualdade de rendimentos); 5) ambos os tipos de capital (público e privado) parecem ter tido um efeito amplificador na intensidade energética de longo prazo da América Latina e Caraíbas; 6) os *stocks* de capital público e privado não demonstraram ser fatores determinantes para a formação dos clubes.

Através destes resultados podemos concluir que existe, de facto, uma falta de investimento em capital físico na América Latina e Caraíbas e que, por isso, por forma a promover o desenvolvimento da região, os governos regionais deverão aumentar os seus níveis de investimento (através de melhores métodos de financiamento) e criar condições para atrair investimento privado, desenvolvendo estratégias que permitam que os capitais público e privado atuem como complementos. Deverão ainda melhorar a qualidade de seus projetos de investimento, bem como os seus critérios de seleção, canalizando uma parte significativa dos novos investimentos para as áreas mais pobres/subdesenvolvidas, criando também incentivos para o investimento privado chegar a essas áreas. Finalmente, deverão garantir que o novo capital físico seja mais eficiente do ponto de vista energético e criar medidas que incentivem o setor privado a seguir essa mesma tendência.

Palavras-chave

Stock de Capital Público; Stock de Capital Privado; Crescimento Económico; Desigualdade de Rendimentos; Intensidade Energética; Países da América Latina e Caraíbas.

Resumo Alargado

Não existem grandes dúvidas acerca do potencial de crescimento da região da América Latina e Caraíbas. No entanto, devido a uma série de problemas estruturais que afetam as economias desta região, o seu processo de desenvolvimento continua aquém do esperado. Ao percorrer a literatura sobre o desenvolvimento desta região, encontramos vários fatores que podem ser apontados como justificações para o atraso no processo de desenvolvimento da América Latina e Caraíbas, como por exemplo a sua instabilidade política, os seus altos níveis de corrupção e de desigualdade, a grande dependência das suas economias na exploração e exportação de recursos naturais, entre outros. Contudo, para além dos fatores previamente enunciados, existem outros que, embora pertinentes, tem tido um menor grau de atenção por parte dos investigadores.

Um desses fatores é sem dúvida a possível falta de investimento da América Latina e Caraíbas em capital físico, nomeadamente em infraestruturas. Segundo alguns investigadores, a falta de novos investimentos, bem como a falta de investimento na manutenção do capital existente, parece estar a contribuir para comprometer os objetivos de desenvolvimento desta região. Por isso mesmo, é natural que várias organizações/instituições internacionais (como o Fundo Monetário Internacional) tenham vido recentemente alertar os governos desta região para a necessidade de fazer esforços neste campo. Desta maneira, consideramos que o estudo da relação entre o capital físico da região e o seu desenvolvimento torna-se importante não só por forma a perceber como o capital se materializou nestas economias (e perceber quais foram os seus efeitos), mas principalmente por forma a ajudar os decisores políticos regionais na elaboração das suas estratégias de investimento futuras.

Podemos considerar que a falta de estudos sobre este tema se prendeu sobretudo com o facto de que, até há bem pouco tempo, não existia um sistema estatístico robusto que permitisse a criação de bases de dados ou recolha de informação, de forma consistente e continuada, sobre os *stocks* de capital. No entanto, com o recente lançamento, por parte do Fundo Monetário Internacional, de uma extensa base de dados sobre os *stocks* de capital público e privado (bem como sobre o investimento público e privado) a tarefa ficou muito mais facilitada. Por isso mesmo, tirando partido destes dados e considerando que o *stock* de capital representa o capital físico disponível numa determinada economia num determinado momento (representeando, em grande parte, as suas infraestruturas), decidimos explorar a evolução de ambos os tipos de capitais na região da América Latina

e Caraíbas, bem como investigar os impactos que eles tiveram em três diferentes domínios de desenvolvimento, mais precisamente em três variáveis principais: crescimento económico, desigualdade de rendimentos e intensidade energética.

Basicamente, a escolha destas três variáveis prendeu-se com o facto de que para promover o desenvolvimento da região, os governos da América Latina e Caraíbas não deverão apenas centrar os seus esforços na melhoria da sua produção económica, mas deverão também tentar atenuar os seus altos níveis de desigualdade de rendimentos, uma vez que a região continua a figurar entre as regiões do mundo com maiores níveis de desigualdade, e procurar maiores níveis de eficiência energética, especialmente devido ao impressionante aumento do consumo de energia da região nas últimas décadas.

Num primeiro ensaio, foi feita uma análise descritiva à evolução de ambos os *stocks* de capital público e privado e investimento público e privado na região da América Latina e Caraíbas entre 1970 e 2017, recorrendo aos dados do Fundo Monetário Internacional. Ao mesmo tempo fizemos também uma análise à evolução da conjuntura económica e da própria política económica da região, tentando perceber os seus efeitos na diminuição/aumento do capital na região. Além disso também efetuámos comparações com regiões com padrões de desenvolvimento semelhantes aos da América Latina e Caraíbas, nomeadamente com o caso da região do Leste Asiático e Pacífico.

Através da nossa análise conseguimos perceber que: 1) a evolução de ambos os capitais foi constantemente influenciada pela conjuntura económica da região (como seria expectável); 2) que o investimento público da região foi sempre relativamente baixo, especialmente quando comparado com o de regiões similares, atingindo um máximo de 6% do produto interno bruto (PIB) somente em 1979, 1980, 1981; 3) que o investimento privado foi sempre bastante volátil, apresentando picos/quedas de grande dimensão dependendo do facto de a região estar a passar por períodos de expansão/contração económica; 4) relativamente aos *stocks* de capital público e privado em percentagem do produto interno bruto (PIB), os dados mostraram que, embora estes tenham aumentado desde a década de 1970, a sua evolução foi lenta e por vezes quase constante.

Todos estes fatos parecem apontar para a baixa capacidade da América Latina e Caraíbas em investir em capital físico nas últimas décadas, reforçando a ideia de que existe realmente uma falta capital físico na região. Deste modo, e seguindo as observações da nossa análise, consideramos fundamental que os governos da América Latina e Caraíbas aumentem os seus níveis de investimento público em capital físico, nomeadamente em

infraestruturas, de forma a poder promover o desenvolvimento da região. Contudo, alertamos para o facto de que esse investimento deve ser bem planeado e não deve assentar numa estratégia de endividamento similar à da década de 1970. Além disso, também achamos necessário que estes governos desenvolvam medidas por forma a reduzir a volatilidade do investimento privado, especialmente para evitar a massiva fuga de investimento/capital privado em tempos de recessão económica.

Depois desta primeira análise, onde recorremos sobretudo à análise gráfica dos dados do Fundo Monetário Internacional, no segundo ensaio presente nesta tese realizámos uma análise empírica à relação entre o *stock* de capital público, *stock* de capital privado e crescimento económico para a região da América Latina e Caraíbas, utilizando um painel de 30 países desta região com um horizonte temporal de 1970 a 2014. A nossa análise baseou-se no uso da metodologia *panel vector autoregressive* (PVAR), para identificar os efeitos de curto prazo e as relações de causalidade de *Granger* entre as variáveis, e no uso dos estimadores *panel dynamic ordinary least squares* (PDOLS) e *panel fully modified ordinary least squares* (PFMOLS), para identificar os impactos de longo prazo do *stock* de capital público e do *stock* de capital privado no crescimento económico dos países da nossa amostra.

Antes de estimarmos os modelos, foram realizados vários testes preliminares e testes de especificação com a finalidade de compreender as características das variáveis e dos países em análise e por forma a garantir que as condições necessárias para a estimação eram cumpridas. Estes foram: 1) estatísticas descritivas; 2) teste de *cross-sectional dependence* (CD); 3) matriz das correlações; 4) *variance inflation factor* (VIF); e 5) teste de raízes unitárias de 2ª geração, também conhecido como *cross-sectionally augmented Im, Pesaran and Shin* (CIPS). No caso do PVAR, foram adicionalmente estimados o teste de *Hausman* e o teste *lag order selection criteria* e no caso do PDOLS e PFMOLS foi ainda estimado o teste de cointegração de *Westerlund*. Depois de estimar o PVAR de 1ª ordem com a variáveis em primeiras diferenças dos logaritmos e com a opção *gmmstyle* e de, subsequentemente, confirmar a sua estabilidade através da *eigenvalue stability condition*, realizámos ainda o teste de causalidade de *Granger*, a *forecast error variance decomposition* (FEVD) e as *impulse response functions* (IRF's).

De acordo com os resultados do modelo PVAR, no curto prazo, o crescimento económico tem um efeito positivo tanto no capital público como no capital privado, o capital privado apenas demonstra um efeito positivo no crescimento e o capital público demonstra efeitos negativos tanto no capital privado como no crescimento. O teste de causalidade de *Granger* parece confirmar estes resultados, mostrando evidências da existência de: 1)

uma causalidade bidirecional entre o crescimento económico e o capital público (positiva no sentido do crescimento para o capital público e negativa no sentido do capital público para o crescimento); 2) uma causalidade bidirecional entre o crescimento económico e o capital privado (positiva em ambos os sentidos); e 3) uma causalidade unidirecional do capital público para o capital privado (negativa). Adicionalmente os resultados da FEVD e das IRF's reforçaram os efeitos que foram encontrados no modelo PVAR e no teste de causalidade de *Granger*. Finalmente, através da estimação do PDOLS e PFMOLS (com as variáveis em logaritmos), verificámos que, no longo prazo, tanto o capital público como o capital privado parecem promover o crescimento económico, com ambas as variáveis a demonstrar um efeito positivo no produto interno bruto (PIB) *per capita* em ambos os estimadores.

De acordo com os resultados obtidos podemos concluir que os governos da América Latina e Caraíbas deverão continuar a promover o investimento público em capital físico ao mesmo tempo que criam/melhoram as condições para encorajar o investimento privado, isto porque tanto o capital público como o capital privado parecem contribuir positivamente para o crescimento de longo prazo desta região. No entanto, dados os efeitos negativos que foram observados no curto prazo por parte do capital público, pensamos que existe a necessidade de prestar uma maior atenção à forma como o investimento público se materializa nesta região, principalmente devido à possibilidade de este poder desencorajar o investimento privado e poder ter efeitos negativos nas contas públicas destes países. Deste forma, achamos que é imperativo melhorar a seleção, avaliação e gestão dos projetos de investimento público, bem como aprimorar os seus instrumentos de financiamento.

Depois de explorar a relação entre o capital público, capital privado e crescimento, no terceiro ensaio desta tese focámos a nossa análise na investigação dos impactos de ambos os capitais num dos maiores problemas socioeconómicos da região: a desigualdade de rendimentos. Para realizar a nossa análise recolhemos dados relativos ao *stock* de capital público, *stock* de capital privado e ao índice de *Gini* para um painel de 18 países da região da América Latina e Caraíbas de 1995 a 2017. A análise empírica foi baseada na utilização do modelo *panel autoregressive distributed lag* (PARDL), construindo três modelos diferentes com diferentes variáveis de interesse: 1) Modelo I com o capital total (soma do capital público e capital privado); 2) Modelo II apenas com o capital público; Modelo III apenas com o capital privado. A variável dependente foi a mesma em todos os modelos (índice de *Gini*), assim como as variáveis de controlo, que tanto no Modelo I, II e III foram o produto interno bruto (PIB), o índice de desenvolvimento humano (IDH),

comércio em percentagem do PIB, receita fiscal em percentagem do PIB e taxa de desemprego em percentagem do total da força de trabalho.

Tal como na análise empírica efetuada no ensaio anterior, antes da estimação dos modelos foram realizados uma série de testes preliminares e testes de especificação, nomeadamente: 1) matriz das correlações; 2) *variance inflation factor* (VIF); 3) teste de *cross-sectional dependence* (CD); 4) estatísticas descritivas; 5) *cross-sectionally augmented Im, Pesaran and Shin* (CIPS); 6) teste de *Hausman* entre efeitos fixos e aleatórios; 7) teste de *Hausman* entre os estimadores *mean group* (MG), *pooled mean group* (PMG) e *pooled*; 8) teste modificado de *Wald*; 9) teste de *Pesaran*; 10) teste de *Frees*; 11) teste de *Friedman*; e 12) teste de *Wooldridge*. Seguindo os resultados dos testes de especificação, uma primeira versão dos modelos foi estimada através do estimador *Driscoll and Kraay (DK)* com efeitos fixos. De seguida, tendo em conta que algumas das variáveis não se mostraram estatisticamente significantes em nenhum dos modelos, decidimos retirá-las da estimação, dando origem a uma versão mais parcimoniosa dos modelos. Por fim, foram ainda adicionadas um conjunto de variáveis *dummy* aos modelos para controlar os choques que podem ter afetado os níveis de desigualdade de rendimento nestes países.

No geral, os resultados das versões parcimoniosas e não parcimoniosas dos modelos, bem como das versões corrigidas para os efeitos dos choques, parecem ser similares, indicando que o crescimento económico parece ser uma ferramenta poderosa para reduzir a desigualdade de rendimentos, que o aumento do desemprego contribui para ampliar a diferença de rendimentos e que o índice de desenvolvimento humano (IDH), a receita fiscal e o comércio também contribuem para reduzir a desigualdade (contudo, os efeitos destas três variáveis só se mostraram estatisticamente significantes no longo prazo). No que diz respeito às nossas variáveis de interesse, todos os modelos (em todas as suas versões) também parecem revelar informações similares: o *stock* de capital total, *stock* de capital público e *stock* de capital privado demonstram efeitos positivos (isto é, efeitos intensificadores) e estatisticamente significantes sobre a desigualdade de rendimentos, mas apenas no curto prazo. No longo prazo, nenhuma destas variáveis apresentou um efeito estatisticamente significante sobre a desigualdade de rendimentos.

Tendo em conta estes resultados, pensamos ser necessário que os governos da América Latina e Caraíbas repensem suas estratégias de investimento em capital físico, principalmente porque o efeito indesejável encontrado no curto prazo pode provavelmente derivar dos investimentos terem sido maioritariamente realizados nas áreas onde já existia um certo nível de desenvolvimento/riqueza, ignorando as áreas

onde os investimentos em capital físico são realmente necessários, ou seja, nas áreas mais pobres/subdesenvolvidas. Neste sentido, pensamos que os governos da região devem, em primeiro lugar, melhorar a gestão e os critérios de seleção dos investimentos públicos de forma a desenvolver as zonas mais pobres/rurais, ligando-as às zonas mais ricas onde existe uma atividade económica mais próspera, permitindo, assim, uma maior convergência em termos de rendimento. Também achamos que pode ser importante que estes governos criem incentivos para que a iniciativa privada invista nessas áreas pois, caso contrário, é muito improvável que isto aconteça. Embora o efeito nefasto do *stock* de capital sobre a desigualdade pareça desaparecer no longo prazo, vemos que o investimento parece ainda não ser suficiente para produzir um efeito redutor na desigualdade de rendimentos. Sendo assim, reforçamos a ideia de que existe a necessidade de aumentar os níveis de investimento em capital físico na região, especialmente nas áreas onde o capital físico é mais escasso, acompanhando este aumento com a melhoria da qualidade dos projetos de investimento.

Finalmente, no quarto ensaio, realizámos uma análise ao papel do capital público e capital privado na intensidade energética da região da América Latina e Caraíbas, começando pela estimação dos impactos de ambos na intensidade energética através de um modelo *panel autoregressive distributed lag* (PARDL). Para realizar esta análise foram recolhidos dados referentes ao *stock* de capital público, *stock* de capital privado, produto interno bruto (PIB) e consumo de energia primária para um painel de 21 países da região da América Latina e Caraíbas, para um horizonte temporal de 1970 a 2014. Para calcular a intensidade energética foi efetuado um rácio entre o consumo de energia primária e o produto interno bruto (PIB). Adicionalmente, como variáveis de controlo, foram incluídas no modelo as variáveis: emissões de dióxido de carbono (CO2) em toneladas métricas *per capita*, produto interno bruto (PIB) *per capita* e o índice anual dos preços das *commodities* de energia.

Mais uma vez, como nas análises efetuadas nos ensaios anteriores, realizámos vários testes preliminares e de especificação: 1) estatísticas descritivas; 2) teste de *cross-sectional dependence* (CD); 3) *cross-sectionally augmented Im, Pesaran and Shin* (CIPS); 4) teste de raízes unitárias *augmented Dickey- Fuller* (ADF) e *Kwiatkowski, Phillips, Schmidt, and Shin* (KPSS); 5) teste de cointegração de *Westerlund*; 6) matriz das correlações; 7) *variance inflation factor* (VIF); 8) teste de *Hausman* entre efeitos fixos e aleatórios; 9) teste de *Hausman* entre os estimadores *mean group* (MG), *pooled mean group* (PMG) e *fixed effects* (FE); 10) teste de efeitos fixos temporais; 11) teste modificado de *Wald; 12)* teste de *Pesaran*; 13) teste de *Frees*; 14) teste de *Friedman*; 15) teste *Breusch Pagan LM*; e 16) teste de *Wooldridge*. Tal como no caso da estimação

efetuada no ensaio anterior, os resultados dos testes de especificação voltaram a induzir-nos no uso do estimador *Driscoll and Kraay* (DK) com efeitos fixos para a estimação adequada do modelo. Mais uma vez, depois de uma primeira estimação, voltámos a estimar o modelo retirando as variáveis que não demonstraram efeitos estatisticamente significantes na variável dependente, dando origem a uma versão mais parcimoniosa do modelo. No entanto, tanto a versão parcimoniosa como a não parcimoniosa revelaram resultados semelhantes.

De acordo com os resultados do PARDL (parcimonioso e não parcimonioso), no curto prazo, tanto o produto interno bruto (PIB) *per capita* como o índice anual dos preços das *commodities* de energia parecem demonstrar um efeito estatisticamente significante na variável dependente. Contudo, enquanto que a primaria variável parece contribuir para a redução da intensidade energética dos países da América Latina e Caraíbas, a segunda parece apresentar o efeito contrário. Relativamente ao longo prazo, vemos que, em primeiro lugar, ambas as variáveis de interesse, capital público e capital privado, parecem contribuir para o aumento da intensidade energética de longo prazo na região, com o capital privado a mostrar um efeito de maior magnitude do que capital público. Em segundo lugar, vemos que o índice de preços das *commodities* de energia (ou energéticas) continuam a demonstrar um coeficiente positivo, o que significa que continuam a ter um efeito potenciador da intensidade energética no longo prazo. Finalmente, as emissões de dióxido de carbono (CO_2) em toneladas métricas *per capita* parece ser a única das variáveis incluídas no modelo que demonstra um efeito redutor na intensidade energética no longo prazo.

Seguindo estes resultados, verificamos que o *stock* de capital público e o *stock* de capital privado estão longe de ser responsáveis pela tendência decrescente da intensidade energética verificada na região, com os resultados a apontar para um efeito potenciador de ambos os capitais na intensidade energética dos países da América Latina e Caraíbas no longo prazo. Isto quer dizer que, provavelmente, o capital físico da região ainda é muito intensivo em energia e precisa ser atualizado, tanto no setor público quanto no privado. A falta de investimento em novos equipamentos e infraestruturas (mais energeticamente eficientes) parece impedir que esta região atinja um nível de intensidade energética ainda mais baixo.

Depois de analisados os impactos de ambos os capitais na intensidade energética, decidimos explorar mais profundamente a relação entre estas variáveis, começando por utilizar o método *log t regression test* e *club clustering algorithm* para verificar se os países da América Latina e Caraíbas convergiam todos para o mesmo estado estacionário

em termos de intensidade energética ou se convergiam para diferentes equilíbrios. De acordo com os resultados, os países da América Latina e Caraíbas agrupam-se em quatro clubes de convergência e um grupo divergente, sendo o "Clube 1" o clube mais energeticamente intensivo e o "Clube 4" o menos intensivo. Desta forma, podemos concluir que os países do "Clube 1" e do "Clube 2" parecem necessitar de fazer um esforço adicional para reduzir os seus níveis de intensidade energética, principalmente quando comparados com os do "Clube 3" e do "Clube 4".

Embora esta conclusão seja valiosa, o principal objetivo da análise dos clubes de convergência foi encontrar uma variável de resposta ordinal (representando o clube ao qual um país pertence) que pudéssemos usar como variável dependente num modelo *ordered logit* para investigar se os *stocks* de capital são determinantes para a formação dos clubes de convergência em termos de intensidade energética. A variável ordinal representa o clube ao qual um determinado país pertence, assumindo valores de 1 a 4. Esta variável é uma variável ordinal porque os clubes podem ser ordenados de acordo com sua intensidade energética, ou seja, quanto maior o valor (de 1 a 4), menor a intensidade de energia. Desta forma, estimámos então duas especificações do modelo *ordered logit*, uma com as médias dos *stocks* de capital público e privado em percentagem do PIB entre 1970 e 2014 e outra com os *stocks* de capital público e privado em % médias anuais entre 1970-2014. A variável intensidade energética inicial foi incluída como variável de controlo em ambas as especificações. Olhando para os resultados dos modelos, verificamos que, ao contrário da intensidade energética inicial, nenhum dos *stocks* de capital parece ser um determinante para a formação dos clubes. Devido a estes resultados concluímos que a diferença dos clubes em termos de intensidade energética advém de outros fatores, com os efeitos de ambos os tipos de capital a serem semelhantes na maioria dos países em análise. Isto quer dizer que a conclusão retirada da estimação do PARDL de que é necessário que a região invista em capital novo e mais energeticamente eficiente pode ser estendida a todos os países desta região, independentemente do seu clube.

Baseado nos resultados da nossa análise, achamos que os governos da América Latina e Caraíbas devem aumentar o seu investimento em capital físico mais energeticamente eficiente, não só no que toca às suas infraestruturas, mas também nos equipamentos e máquinas que são utilizados no processo de produção. Ao mesmo tempo, devem criar (ou melhorar) as leis e a regulação relativa à eficiência energética, criando também incentivos que permitam que o capital privado siga a mesma tendência de redução de intensidade energética (aumento de eficiência energética). Finalmente, dado que o investimento em capital físico mais eficiente é uma necessidade para toda a região da

América Latina e Caraíbas, a discussão, formulação e promoção de medidas voltadas para o uso mais eficiente da energia devem estar firmemente presentes nas agendas dos organismos regionais, podendo estes servir de palco para a criação e promoção de medidas de eficiência energética e para a construção de um plano de promoção da eficiência energética mais homogéneo na região.

Juntos, os resultados desta tese parecem indicar que, para promover o desenvolvimento económico, social e sustentável da região, os governos da América Latina e Caraíbas precisam de: i) aumentar os seus níveis de investimento em capital físico, melhorando os seus métodos de financiamento, e ao mesmo tempo criar condições para atrair investimento privado, desenvolvendo estratégias que permitam que o capital público e privado atuem como complementos; ii) melhorar a qualidade dos seus projetos de investimento (preparação, estruturação e implementação), bem como os critérios de seleção desses investimentos, por forma a canalizar uma parte significativa para as áreas mais pobres/subdesenvolvidas, criando incentivos para que o investimento privado também chegue a essas áreas; iii) garantir que o novo capital físico seja mais eficiente do ponto de vista energético, investindo na manutenção e atualização do capital existente e criando medidas que incentivem o setor privado a seguir essa mesma tendência.

Abstract

According to the conclusions of the reports of several international institutions, such as the International Monetary Fund, the Latin American and Caribbean region has suffered from a lack of investment in physical capital in recent decades. This is especially true if one looks at both the levels and the state of their infrastructures. As might be expected, this is not a desirable situation, mainly because, according to the same reports, it can give rise to several harmful effects on the economies of this region. That said, it is natural that there is less and less doubt about the fact that in order to promote the development of the Latin American and Caribbean region, it will, in the near future, have to be able to increase its levels of physical capital.

Considering the facts stated above, several essays were prepared in this thesis in order to (1) assess the impacts of physical capital on the development of the region; and (2) help the regional policy makers in the development of their future investment strategies. It was taken advantage of the data on public and private capital that was recently made available by the International Monetary Fund to achieve these objectives. Initially, the idea was only to use the data on the public capital stock since it is the one that is linked to the government's provision of economic and social infrastructure. However, as the private capital stock data was also available, it was also included in the analysis. Why stocks? Because in this way, instead of just accounting for the annual flows of public and private investment (only capital increases), it accounts for the volume of existing capital, as well as for the effects of depreciation.

The first essay was based on the historical analysis of the evolution of both types of capital in the Latin American and Caribbean region from 1970 to 2017, in order to be able to verify if there was, in fact, a lack of investment in physical capital in this region. Using the data from the International Monetary Fund, the progress of investment and stocks in this region during the previously stated period was graphically analysed, accompanying this analysis with, pass the redundancy, the analysis of the economic conjuncture of the region and with comparisons with the evolution of the physical capital in similar regions. The results of this analysis seem to confirm the hypothesis that this region suffers from a lack of investment in physical capital, with the Latin American and the Caribbean being characterised by a relatively low level of public investment (especially when compared to similar regions), by a very volatile private investment and

by a very slow evolution (in some periods almost constant) of its public and private capital stocks as a percentage of gross domestic product (GDP).

After this more descriptive analysis, the three essays that followed were based on empirical analysis applied to Latin American and Caribbean countries panels, in order to study the effects from both capital stocks on the region's economic growth, on the region's income inequality levels and on the region's energy intensity, respectively. In this way, it was possible to evaluate the contributions that public and private capital stocks had in various development fields, namely in the economic, socioeconomic and sustainable fields.

Regarding the methodologies that were used, in the second essay of this thesis, where the relationship between the capital stocks and economic growth was investigated, the panel vector autoregressive (PVAR) methodology was used to study the short-run impacts and Granger's causalities, whereas the panel dynamic ordinary least squares (PDOLS) and panel fully modified ordinary least squares (PFMOLS) estimators were used to study the long-run impacts. In the third essay, where the impacts of both capital stocks on income inequality were analysed, the panel autoregressive distributed lag (PARDL) model and the Driscoll-Kraay (DK) estimator with fixed effects were used to study the short- and long-run impacts of the variables. Finally, in the fourth essay, where the role of public capital stock and private capital stock in the region's energy intensity was studied, the panel autoregressive distributed lag (PARDL) model and the Driscoll-Kraay (DK) estimator with fixed effects were again used to study the short- and long-run impacts of the variables. In addition, the log t regression test method and the club clustering algorithm were also used in order to investigate the various convergence clubs in terms of energy intensity, whereas the ordered-logit model was used to verify whether capital stocks were important determinants for the club's formation.

The results from the essays seem to indicate that: 1) both public and private capital had a positive effect on the long-run economic growth of the Latin American and the Caribbean countries; 2) in the short-run, public capital seems to have had negative effects on both growth and private capital (crowd-out effect); 3) the capital stock (public, private and total) seems to have contributed to the increase in income inequality in the short-run; 4) in the long-run, this effect seems to disappear (which still does not demonstrate a contribution of physical capital to the reduction of income inequality); 5) both types of capital (public and private) appear to have had an enhancing effect on the long-run energy intensity of the Latin America and the Caribbean countries; 6) the public

and private capital stocks did not prove to be determinant factors for the formation of the clubs.

Through these results, it can be concluded that there is, in fact, a lack of investment in physical capital in Latin America and the Caribbean and that, therefore, in order to promote the development of the region, regional governments should increase their investment levels (through better financing methods) and create conditions to attract private investment, at the same time as they develop strategies that allow to public and private capital to act as complements. They should also improve the quality of their investment projects, as well as their selection criteria, channelling a significant part of the new investments to the poorest/underdeveloped areas, creating incentives for private investment also to reach these areas. Finally, they must ensure that the new physical capital is more energy-efficient and should create measures to encourage the private sector to follow this same trend.

Keywords

Public Capital Stock; Private Capital Stock; Economic Growth; Income Inequality; Energy Intensity; Latin American and Caribbean Countries.

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Acronyms List

ADF	Augmented Dickey-Fuller
CD	Cross-section Dependence
CIPS	Cross-sectionally Augmented Im, Pesaran and Shin
CO2	Carbon Dioxide
DK	Driscoll and Kraay
EA	East Asia
EAP	East Asia and Pacific
ECLAC	Economic Commission for Latin America and the Caribbean
ECM	Error Correction Mechanism
EU	European Union
FE	Fixed Effects
FEVD	Forecast Error Variance Decomposition
GDP	Gross Domestic Product
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IMF	International Monetary Fund
IRF's	Impulse Response Functions
KPSS	Kwiatkowski, Phillips, Schmidt, and Shin
LA	Latin American
LAC	Latin America and the Caribbean
LLC	Levin, Lin and Chu
LM	Lagrange Multiplier
MG	Mean Group
OECD	Organisation for Economic Co-operation and Development
OLADE	*Organización Latinoamericana de Energia*
OLS	Ordinary Least Squares
OPEC	Organisation of the Petroleum Exporting Countries
PARDL	Panel Autoregressive Distributed Lag
PDOLS	Panel Dynamic Ordinary Least Squares
PFMOLS	Panel Fully Modified Ordinary Least Squares
PIM	Perpetual Inventory Method
PMG	Pooled Mean Group
PPP	Public-Private Partnership
PVAR	Panel Vector Autoregression
R&D	Research and Development
RE	Random Effects
SDGs	Sustainable Development Goals
SWIID	Standardised World Income Inequality Database
TFP	Total Factor Productivity
UECM	Unrestricted Error Correction Model
UN	United Nations
US	United Sates
VAR	Vector Autoregression
VECM	Vector Error Correction Model

VIF	Variance Inflation Factor

Chapter 1

Introduction

Although the Latin America and Caribbean (LAC) region has enormous growth potential, the region suffers from several problems (e.g. high social and political instability, high levels of corruption and inequality, high dependence on natural resources exploitation and exportation, public finance management problems) which contribute to undermining its desired development. Due to this, it becomes crucial that researchers from several areas of knowledge help the LAC policymakers with the results from their investigations in a joint effort to develop policies directed towards the promotion of the economic, social and sustainable development of this region.

In accordance, in the earliest stages of this research, some prominent regional issues were identified (especially those with a considerable lack of attention from the empirical literature and that could be more deeply investigated). One of these issues was linked with the possibility that the LAC may be suffering from an "*infrastructure gap*", which could be (and could have been) harmful for their economic sustainability and development (Perrotti, 2011).

In fact, following the advice from several international organisations, such as the International Monetary Fund (IMF), it seems that the region will probably need to raise their investment in physical capital in the near future, or there is a risk that this gap may gradually hamper the region's growth and development (Faruqee, 2016). So, how can we measure physical capital?

With the release of the "*Investment and Capital Stock Dataset*" by the IMF (2017), data on public and private capital stocks became available for a sample of around 170 countries from 1960 until 2017 (and on public-private partnerships (PPPs) capital stock too, but at a much lower degree). Since a large amount of data was available for the LAC countries, it was thought that perhaps the hypothesis that the LAC suffers from a lack of physical capital could be verified at a deeper level, making an extended empirical investigation to the effects that both public and private capital stocks had on the region's development.

As it is known, capital stock is considered as one of the primary inputs of the classic production function, representing the available physical capital at a given moment in a

determined economy. Although it represents, in a great deal, a county's infrastructure assets, it also represents other types of physical capital that are used in the production process (e.g. vehicles, machines, tools, etc.).

Contrarily to other production resources, such as raw materials, most of the physical capital is not destroyed in the production process. However, its value usually declines over time (depreciation). Thus, capital stock at a given moment can be obtained by the value of the existing capital (minus the value of its depreciation) plus the value of new investments.

Why use stocks instead of just annual inflows (e.g. public and private investment)? As the IMF (2017, p.1) states, "*it is the volume of the existing network not only additions to it that provide productive services*", plus "*infrastructure assets are subject to wear and tear, hence the need to examine the stock of public capital net of depreciation*".

In fact, initially, the focus of the analysis was on the effects of public capital stock. This because it is directly associated with the government's investment decisions, representing, for example, the construction of schools, hospitals, highways, airports, and other types of social and economic utilities. However, as private capital data was also available, the scope was extended to account for this variable's effects.

Thus, wanting to study the effects of both types of capital on the region's development, but knowing that the concept of development is, in itself, very broad, it was decided that this analysis should be focused on three different development domains. More precisely, on three main variables: economic growth, income inequality, and energy intensity.

Why economic growth? Because it is an indicator that shows (in a great deal) if a country/region is on the right development path. It is a tool that the countries can use to achieve various macroeconomic objectives, being present in one of the so-called Sustainable Development Goals (SDGs) from the United Nations (UN), more precisely in the eight-goal: "*Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*" (see UN General Assembly, 2015, p. 14).

Moreover, it is natural that one should analyse the relationship between capital stock and economic growth because, as it was previously stressed, capital stock is one of the primary inputs of the production function. Indeed, it is known that countries need a determined level of physical capital to grant a sound and sustainable economic performance - which seems not to be the case of the LAC (Cavallo and Powell, 2019).

Why income inequality? Because, although the previous statement, there are more standards that the countries/regions need to attain in order to consider them as developed ones. Since the LAC continues to stand among the regions with the highest income inequality levels (UN, 2020), it also becomes important to analyse the effects of physical capital on income inequality in this region.

The importance of such an analysis is reinforced by the negative effects that income inequality and that the lack of physical capital (primarily infrastructure) can have on the poor strata of the LAC population and on the region's development aspirations (Cavallo et al., 2020; OECD, 2019; Cavallo and Powell, 2019). Moreover, it should also be mentioned that the reduction of poverty and inequality is also included in the SGDs, namely in the first and tenth goals (see UN General Assembly, 2015, p. 14).

Why energy intensity? Because capital and energy are intrinsically connected. Buildings, vehicles, machines, tools and other types of physical capital require energy to produce goods and services that we need. Thus, it becomes interesting to investigate the effects of the capital stock on energy intensity, especially in LAC, where the increased worries with the energy demand and energy security (Koengkan et al., 2019; Balza et al., 2016) increased the demand for energy efficiency (and for lower levels of energy intensity).

Moreover, the justification to address this relationship in the LAC is reinforced by its possible lack of investment in physical capital. This because this lack of investment presuppose that its physical capital may be outdated and still be very energy-intensive, which, in the end, may contribute to compromising the achievement of several SGDs, such as the eighth, ninth, eleventh, twelfth and thirteenth (see UN General Assembly, 2015, p. 14).

1.1 Research Overview

Overall, as it can be perceived, the main motivation for the development of this thesis was the need to produce empirical evidence on the effects that the LAC capital stock has had on the region's development. This because, first, due to the previous lack of suitable data, the literature on this topic was still very scarce. Second, due to its lack of physical capital, the region will probably be obligated to raise their physical capital investment level. Thus, it will need help in the development of appropriate investment strategies.

Thus, the main objective of this thesis is to be able to produce results and conclusions to help the LAC policymakers on the development of strategies and policies that guarantee that the new physical capital investments will be channelised to the economic, social and

sustainable development of the LAC region. Hence, the central question is (as the title describes):

- Is the Latin American and Caribbean capital stock affecting the development of the region?

In order to answer this central question, four different analyses were conducted, originating four essays which are present in this thesis in the following chapters (Chapter 2, Chapter 3, Chapter 4, Chapter 5).

In Chapter 2, data on public and private capital stocks from the "*Investment and Capital Stock Dataset*" (IMF, 2017) for the LAC countries was used in order to analyse the evolution from both types of capital in this region from 1970 until 2017. More precisely, it was used to assess whether there is indeed a lack of physical capital in this region. Thus, the central question from Chapter 2 is:

- Does the Latin America and Caribbean region suffer from a lack of physical capital?

In order to answer this chapter's central question, a descriptive analysis was conducted through the graphical examination of the public and private capital stocks (and investment) historical data. In the analysis, it was made a division between the 1970s, 1980s, 1990s decades and the new millennium (2000-2017).

In addition to the evolution of physical capital, the historical evolution of the economic situation of this region from 1970 to 2017 was also analysed (with, for example, the graphical analysis of important variables as the regional GDP growth rates). Moreover, the region's case was also compared with the one from a similar region, namely with the East Asia and Pacific (EAP).

Overall, from the Chapter 2 analysis, it was possible to observe that the LAC indeed suffers from a lack of physical capital, with the regional public and private capital stocks (as a percentage of GDP) showing a very slow evolution from 1970 to 2017 (indeed, it was nearly constant in some periods). Moreover, it was seen that this region presents (in general) a low level of public investment (it was always behind the one from the EAP) and has difficulties attracting and maintaining private investment in a strong economic contraction context.

This chapter concludes that, as it was previously suspected, there is a need to increase the LAC physical capital in the near future. More precisely, it is necessary to increase the region's low public investment levels and, at the same time, develop measures to attract and maintain private investment.

After confirming the idea that new physical capital investments are needed in the LAC region, it was thought that it was necessary to empirically analyse the effects that public and private capital have had on this region's economies. Thus, the next step was the analysis of the effects that both public and private capital have had on this region's economic growth, with the central question of Chapter 3 being:

- Will an increase in the public and private capital be beneficial to the economic growth of the Latin America and Caribbean region?

To answer this question, the relationship between public capital stock, private capital stock, and economic growth was analysed for a panel of 30 LAC countries for a time span ranging from 1970 to 2014. The methodology was based on the use of the panel vector autoregression (PVAR) estimator developed by Love and Zicchino (2006) and of the panel dynamic ordinary least squares (PDOLS) and panel fully modified ordinary least squares (PFMOLS) estimators developed by Pedroni (2001a, 2001b).

In sum, the findings pointed out that both public and private capital have had a positive effect on the long-run economic growth of the LAC countries. This means that governments should continue to support public and private investment projects or, in other words, that the increase in public and private investment in physical capital will contribute to the enhancement of these countries long-run growth.

Nevertheless, it was also seen that, in the short-run, public capital seems to have produced negative effects on both growth and private capital (crowd-out effect). Therefore, it can be considered that some changes are needed in the financing, planning and execution of the LAC public investment projects in order to avoid these undesirable effects.

Moving on to Chapter 4, after investigating the effects from public and private capital on growth, the analysis was then centred on the empirical investigation of the impacts of public and private capital on the LAC income inequality. The main objective was to verify if they are contributing to softening the income inequality problem or if, conversely, they are enhancing it. Hence, the central question of Chapter 4 is:

- Are the Latin American and Caribbean public and private capital contributing to reducing the region's income inequality?

In order to find the answer to this question, the short- and long-run impacts of the public and private capital stocks (and of the total capital stock) in the income inequality levels of 18 countries from the LAC region were analysed from 1995 to 2017. In this analysis, three different specifications of the panel autoregressive distributed lag (PARDL) model in the form of an unrestricted error correction model (UECM) were used. One specification with public capital stock as the interest variable, another with private capital stock as the interest variable, and another with the total capital stock as the interest variable.

The several specification tests that were conducted pointed to the presence of heteroscedasticity, contemporaneous correlation, and first-order autocorrelation in the three specifications of the PARDL. Due to the presence of these phenomena, the Driscoll and Kraay (DK) estimator, developed by Driscoll and Kraay (1998), with fixed effects (FE), was used in order to estimate all the three models.

Posteriorly, a set of dummy variables were added to the three specifications in order to control for the shocks which may have affected the income inequality levels of these countries. This also allowed to test the robustness of the findings from the previous estimations (i.e. from the specifications without the correction of the shocks).

The overall results from Chapter 4 indicated that capital stock (public, private and total) seems to have contributed to the increase of income inequality in these countries, probably because the previous investments were mostly channelled to the already richer/wealthiest areas. However, this nefarious effect was only verified in the short-run. In the long-run, no statistically significant effect from capital stock on income inequality was detected, either positive or negative.

In sum, this means that there is the need to rethink the LAC physical capital investment projects. In order to reduce income inequality, LAC countries must continue to increase their levels of physical capital investment and, primarily, channel a significant part of them to the region's most underdeveloped areas.

Finally, after the analysis of the effects of the LAC capital stock on the region's growth and income inequality, the attention was tuned to the assessment impact of capital stock on the region's energy intensity. This way, it would be possible to understand if the LAC countries should also raise their demand for more energy-efficient physical capital in

addition to the need to increase their physical capital investment levels, especially in the poorest/undeveloped areas. Thus, in Chapter 5, the role of public and private capital on the LAC energy intensity was investigated in order to answer the following central question:

- Will the Latin America and Caribbean region need to invest in more energy-efficient physical capital?

To achieve the goals of this chapter, the short and long-run impacts of public and private capital stock in the energy intensity of 21 LAC countries were analysed from 1970 to 2014, using the panel autoregressive distributed lag (PARDL) model. Again, due to the phenomena that were identified in the specification tests, the model had to be estimated using the DK estimator, developed by Driscoll and Kraay (1998), with FE.

In order to extend the analysis, the log t regression test method, proposed by Phillips and Sul (2007), and the club clustering algorithm, proposed by Phillips and Sul (2007) and later modified by Schnurbus et al. (2017), were also used. The use of such methods allowed the identification of the LAC countries that converge to different equilibriums in terms of energy intensity (i.e. to identify the different convergence clubs).

In addition to the identification of the clubs, they allowed constructing an ordinal response variable (representing the club to which a country belongs) that could then be used as the dependent variable in an ordered logit regression model. This model was then used to investigate if the public and private capital stocks were responsible for the LAC energy intensity convergence club's formation.

In short, the results from the Chapter 5 estimations indicated that the LAC needs to increase its investment in more energy-efficient equipment and infrastructure. Indeed, the results indicate that both types of capital (public and private) seem to have had an enhancing effect on the long-run LAC energy intensity.

Furthermore, despite the four different convergence clubs that were found, as neither the public nor private capital stocks were considered as determinants for the club formation, this means that the differences of the clubs in terms of energy intensity come from other factors. Hence, it can be assumed that the previous conclusion regarding the need for more energy-efficient physical capital can be extended to all the countries of this region, regardless of their club membership.

Together, the outcomes from this thesis seem to indicate that in order to promote the region's economic, social and sustainable development, the LAC countries governments need to:

1. Increase their physical capital investment levels, with improved financing methods, at the same time as they create the conditions to attract private investment and develop strategies to allow public and private capital to act as complements;

2. Improve the quality of their investment projects (preparation, structuration, and implementation) as also the selection criteria for these investments in order to channelise a significant part of them to the usually forgotten poorest/undeveloped areas, creating incentives for private investment to reach these areas as well;

3. Guarantee that the new physical capital is increasingly more energy-efficient (as also invest in the maintenance and upgrade of the existing capital), creating measures to encourage the private sector to follow this same trend.

1.2 Contributions and Innovations

Beyond the several contributions that this thesis presents to the enrichment of the existing literature on the capital stock topic, it should be particularly stressed the contribution it presents to LAC's political decision-making. With a special emphasis on the one directly associated with the regional physical capital investment strategies.

Starting with Chapter 2, it can be said that its greatest contribution is, in fact, being an extensive analysis of the historical evolution of public and private capital stock and investment in LAC. As far as one knows, it did not exist a similar analysis for this region (at least in such a comprehensive way). Indeed, it can be considered that it is an important input for the physical capital literature in LAC because it allows a clearer understanding of how capital has evolved in this region since the 1970s.

In addition, it also identifies some of the factors that have promoted the increase and decrease of the region's capital during the same period. Ultimately, it is expected that this analysis may lead to an increased interest in the study of this topic in the LAC.

Moving on to Chapter 3, although the relationship between capital stock and economic growth be very often analysed, the most cited study on this topic for the LAC region is the one from Ramirez and Nazmi (2003), which has only covered nine Latin American

(LA) countries from 1983 to 1993. Given that new databases, econometric techniques, and ideas have arisen since its publication, there was the need to expand the study on the impacts of capital stock on this region economic growth and, thus, enhance the literature on this relationship for the LAC region.

Moreover, another improvement from this analysis is that instead of using the usual approach based on the Cobb–Douglas production function, it uses the PVAR methodology. Conversely to the Cobb–Douglas production function, the PVAR methodology was designed to work with endogeneity, and consequently, allows to explore causal relationships in any direction and to investigate indirect links between the variables.

Contrary to the relationship between capital stock and growth, the literature on the effects of capital stock on income inequality is very scarce. Thus, in Chapter 4, an effort was made to enlarge the literature on this thematic with a special emphasis on the case of LAC, which suffers from high levels of income inequality and low levels of physical capital. In addition to this contribution to the literature, this chapter empirical analysis can also be considered innovative due to the inclusion of a new method to test for the existence of peaks/breaks of large magnitude (shocks).

Finally, in Chapter 5, there was a significant contribution to the literature on the determinants of energy intensity, mainly because the relationship between capital stock and energy intensity is still very underexplored. Additionally, this chapter empirical analysis also tried to include a certain degree of innovation, namely through the use of the log t-test proposed by Phillips and Sul (2007) and of the clustering algorithm originally proposed by Phillips and Sul (2007) and later modified by Schnurbus et al. (2017).

With the use of the previously mentioned methods, in addition to the investigation of the impact from public and private capital on energy intensity, it was possible to study the convergence of the sample of countries in terms of energy intensity and find several converge clubs in this region with different levels of energy intensity and different transition paths. Additionally, through the estimation of an ordered-logit regression model, it was also possible to verify if public and private capital were determinants of these clubs' formation.

To conclude the discussion on the contributions from this thesis, it must, once again, be highlighted the importance of the results from all these essays to the development of

suitable physical capital investment strategies in LAC. More properly, it is expected that one of the greatest contributions of this thesis is, through its conclusions and adjacent political implications, to be able to help the LAC policy makers on the development of strategies to promote the region's economic, social and sustainable development.

1.3 Structure

This thesis is composed of four main chapters, from Chapter 2 to Chapter 5. All these chapters are related to the four essays that were produced during these years of research, from 2017 to 2021.

In Chapter 2, entitled "Latin America and the Caribbean Physical Capital", the evolution of both public and private capital stocks and investment in the LAC was explored from 1970 until 2017. The main objective of this chapter was to realize if the idea that the region suffers from a lack of physical capital was actually true.

In Chapter 3, entitled "The relationship between public capital stock, private capital stock, and economic growth in Latin America and Caribbean countries", the relationship between these two types of capital and the economic growth of these region's countries was investigated. This chapter aimed to understand if an increase in the region's physical capital would be beneficial to the LAC countries economic output.

In Chapter 4, entitled "What effect does public and private capital have on income inequality? The case of the Latin America and Caribbean region", the effects of both capitals on income inequality were analysed. This time, the goal was to understand if they had contributed to attenuate the region's income inequality levels or if, conversely, there is a need to change the LAC physical capital strategies so that they could be able to contribute to this end.

In Chapter 5, entitled "An analysis of the energy intensity of Latin American and Caribbean countries: Empirical evidence on the role of public and private capital stock", the impact of both types of physical capital in the region's energy intensity was investigated. In this chapter, the objective was to verify whether the region's physical capital was becoming more energy-efficient, and thus contributing to the LAC decreasing energy intensity trend, or if, on the contrary, there was a need to invest in new and more energy-efficient capital in this region.

Finally, the overall conclusions from the results/outcomes of this thesis, as also their policy implications, are presented in Chapter 6. In addition to the highlight of the main

findings of this thesis, the main limitations of the investigation are also stressed, as well as some future research lines.

Now, describing the structure of each chapter, it can be said that, firstly, Chapter 2 is composed of an introductory section (Section 2.1), by sections that address the evolutions of both types of capital and investment in LAC in different periods of time (Section 2.2, Section 2.3, Section 2.4 and Section 2.5) and, finally, by a section related to this chapter conclusion (Section 2.6).

Then, the structure of the following chapters, from Chapter 3 to Chapter 5, is very similar. Indeed, all of them are structured in the following way: introduction section (Section 3.1, Section 4.1, Section 5.1), literature review section (Section 3.2, Section 4.2, Section 5.2), data and methodology section (Section 3.3, Section 4.3, Section 5.3), results and discussion section (Section 3.4, Section 4.4, Section 5.4), and conclusions and policy implications section (Section 3.5, Section 4.5, Section 5.5).

However, it should be stressed that Section 5.4 from Chapter 5 has three additional divisions, or Subsections, which are: Subsection 5.4.1 devoted to the results and discussion of the PARDL model; Subsection 5.4.2 devoted to the results and discussion of the convergence clubs analysis; and Subsection 5.4.3 devoted to the results and discussion of the ordered logit regression model.

Lastly, Chapter 6 is composed of two subsections. After an overview of this thesis investigation, Section 6.1 displays the concluding remarks, whereas Section 6.2 displays the limitations of this investigation and the future research recommendations.

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Chapter 2

Latin America and the Caribbean Physical Capital

In this chapter, the evolution of the public and private physical capital in the Latin America and the Caribbean (LAC) region was analysed from the 1970s until 2017, recurring to data from the "*Investment and Capital Stock Dataset*" of the International Monetary Fund (IMF). In the analysis, it was noticed that even though the LAC public and private capitals were constantly influenced by the economic conjuncture, the regional public investment was always quite low, reaching the maximum of 6% of the gross domestic product (GDP) only in 1979, 1980, 1981. Regarding private investment, it can be said that it has always had a high degree of volatility, presenting large peaks/troughs depending on if the LAC region was passing through periods of booms or busts. Relatively to the public and private capital stocks as a percentage of GDP, even though the data had shown that both capital stocks have increased since the 1970s, it also showed that they presented a slow, and sometimes nearly constant, evolution. This can be a sign that the LAC region suffers from a lack of physical capital investment that can be very alarming and which can compromise its growth and development. All these facts reinforce the idea that, in the nearly future, the LAC should increase its physical capital investment levels and promote more adequate investment strategies in order to achieve its development goals.

2.1 Introduction

As it was already stressed in Chapter 1, capital stock, which embodies physical capital as vehicles, machines, tools, but mostly infrastructure assets, is one of the primary inputs of the classic production function. Due to this, it is usually considered a significant asset for countries' economic growth prospects. In fact, it is quite consensual that countries' need a certain level of capital investment in order to attain their growth and development goals.

Given its influence on the various stages of the production process, it is considered that a lack of physical capital investment (and/or the lack of maintenance of the existing one) can take several nefarious effects on a country's production and, subsequently, on its overall economic output. Some examples of these nefarious effects are that this fact can

contribute to increase production costs, make it more difficult to obtain the resources and materials needed for the production, and hinder the connection between the producer and the final consumer.

In order to avoid these effects, governments usually use public investment to supply major physical capital assets to their countries (e.g. roads, bridges, railroads, airports, tunnels, etc.). These physical structures are very important in the sense that the productive fabric can use them for exercising their activity. Furthermore, it should not be forgotten that public investment is also important in providing social infrastructure (e.g. schools, hospitals), which, due to its positive effects on human capital, is also extremely important for growth and development.

However, due to the low degree of economic slack, huge public debts, and fiscal consolidation problems that many countries face (especially the developing countries), the private sector can also play a large role in providing infrastructure. In fact, there are several cases where governments often chose to privatise certain infrastructure sectors due to their financial constraints.

Turning to the case of the sample of this doctoral thesis, there is a piece of strong evidence which indicates that the Latin America and the Caribbean (LAC) region could be suffering from an “infrastructure gap”. Following the reports from some international organisations as the United Nations (UN), the International Monetary Fund (IMF) and the World Bank (Faruqee, 2016; Lardé and Sánchez, 2014; Perrotti, 2011; Fay and Morrison, 2007), if the region does not raise their investment in physical capital in the near future, there is a risk that this gap may gradually hamper the region's growth and lead to several undesirable effects in its economic sustainability, development, and competitivity.

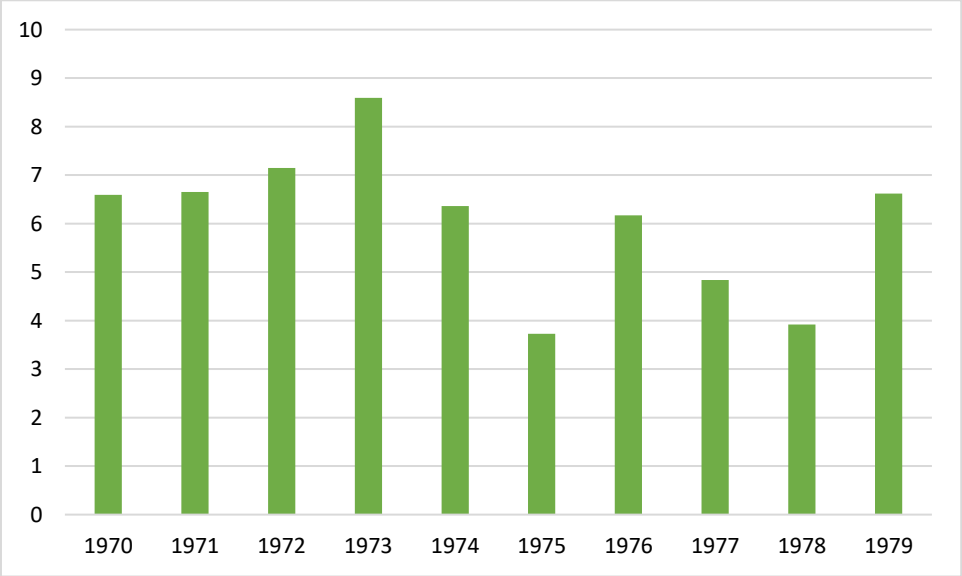
Due to this, before proceeding with the analysis of the effects from the LAC capital stock on the region's development, it is important to analyse the historical evolution of physical capital in the LAC region from the 1970s to 2017 (the year up to which data was available). As it was previously stressed, this will allow verifying if there is, in fact, a lack of physical capital in this region.

Therefore, in Section 2.2 of this chapter, it will be presented an analysis of the evolution of the LAC physical capital in the 1970s, in Section 2.3, it will be presented an analysis to the evolution of the LAC physical capital in the 1980s, in Section 2.4 an analysis to the evolution of the LAC physical capital in the 1990s, and in Section 2.5 an analysis to the

evolution of the LAC physical capital in the new millennium (from 2000 to 2017). In Section 2.6, the public investment in physical capital from the LAC will be compared with the one from East Asia and Pacific and it will be presented data from the "Global Infrastructure Outlook" for some of the LAC countries in the analysis. The overall findings of this analysis will be then presented in Section 2.7.

2.2 Physical Capital in Latin America and the Caribbean: 1970s

According to the data from the World Bank, in the 1970s, the LAC region registered a period of considerable economic growth. The regional growth rates were always above 3% (Figure 2.1). Following Zettelmeyer's (2006), during this decade, Latin America (LA) achieved a higher per capita growth than other developing regions, only being surpassed by the East Asia and Pacific (EAP).



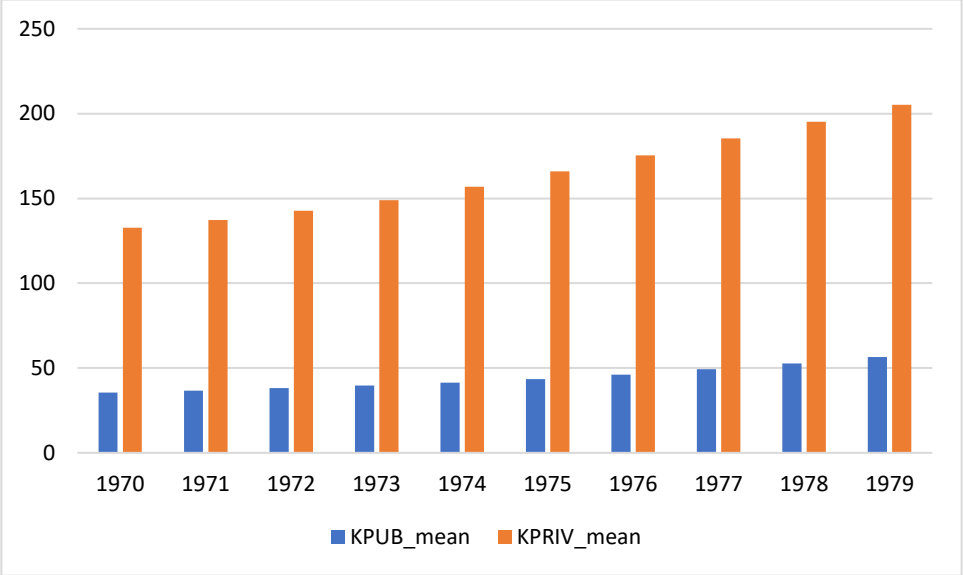
Notes: This graph was created by the author and was based on GDP growth (annual %) data for the LAC aggregate from the World Bank "*World Development Indicators*" database.

Figure 2.1 – GDP growth (annual %) - LAC (1970-1979)

However, not all LAC countries experienced these positive effects. According to Loayza et al. (2005), countries as The Bahamas, Barbados, Belize, and the small island countries have shown a decreasing growth trend since the 1960s and 1970s. Despite this, this decade is seen as one of solid growth for the general LAC (Loayza et al., 2005).

Did the LAC countries take advantage of this positive period to invest in their physical capital? Looking at Figure 2.2, it can be seen that the levels of both types of capital stocks

(in billions of constant 2011 international dollars) grew over time during the 1970s. However, this is far from unexpected, given that it is difficult to see a situation where the value of depreciation surpasses the value of new investments.

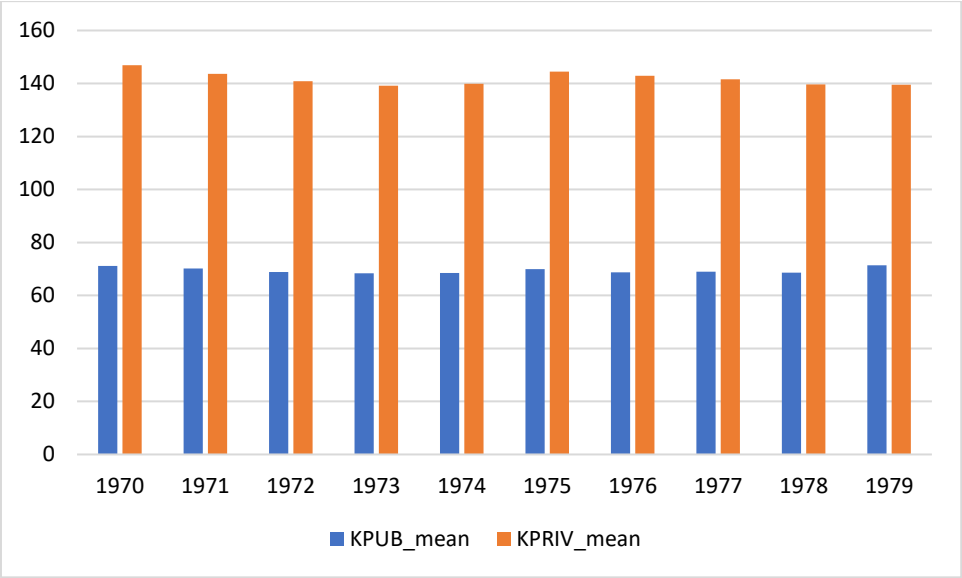


Notes: This graph was created by the author and was based on the data for general government capital stock and private capital stock (both in billions of constant 2011 international dollars) for the LAC countries from the "*Investment and Capital Stock Dataset*" by the IMF (2017). The blue bars represent the mean of public capital stock (KPUB_mean), whereas the orange bars are the mean of private capital stock (KPRIV_mean). LAC countries included: Antigua and Barbuda, Argentina, The Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Uruguay, Venezuela.

Figure 2.2 – Public capital stock and private capital stock (in billions of constant 2011 international dollars) – LAC (1970-1979)

Due to the previous inference, it could be helpful to look at the public and private capital stocks as a percentage of the gross domestic product (GDP). Accordingly, in Figure 2.3, one can see that the evolution of both types of capital (as a percentage of the GDP) was nearly constant during this decade. While the private capital stock was always around 140% of GDP, the public capital stock was always around 70% of GDP.

According to De Jong et al. (2018), when in the percentage of the GDP, if public capital shows a flat or falling evolution, it can be interpreted as a sign of the lack of government investment in the maintenance of existing capital. As the private capital stock shows an identical evolution, this suspicion can also be extended to the private entities.

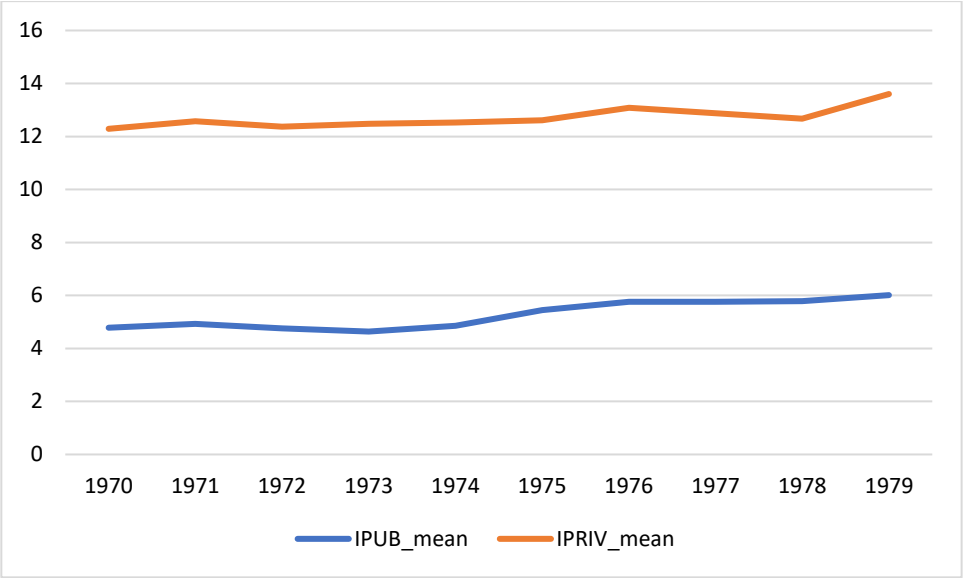


Notes: This graph was created by the author and was based on the data for general government capital stock and private capital stock (both in billions of constant 2011 international dollars) and on the gross domestic product (in billions of constant 2011 international dollars) for the LAC countries from the "*Investment and Capital Stock Dataset*" by the IMF (2017). The blue bars represent the mean of public capital stock (% of GDP) (KPUB_mean), whereas the orange bars are the mean of private capital stock (% of GDP) (KPRIV_mean). LAC countries included: Antigua and Barbuda, Argentina, The Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Uruguay, Venezuela.

Figure 2.3 – Public capital stock and private capital stock (% of GDP) – LAC (1970-1979)

Finally, if one chooses to look only at investment, it can use the public and private gross fixed capital formation data from the "*Investment and Capital Stock Dataset*" by the IMF (2017). To construct the investment flow series, the IMF uses data on gross fixed capital formation, which is then combined with the initial capital stock and depreciation rate, in order to construct the capital stock data.

In Figure 2.4, it is possible to see the evolution of public investment and private investment, both as a percentage of GDP, in the LAC during the 1970s decade. As it can be observed, during this decade, there were periods of both increases and decreases in public and private investment. However, at the end of the decade, both types of investment achieved a maximum value of 13.6 % of GDP in the case of private investment and 6% of GDP in the case of public investment. This shows that the LAC made a moderate effort in order to increase its investment in physical capital during the 1970s.



Notes: This graph was created by the author and was based on the data for general government investment (gross fixed capital formation) and private investment (gross fixed capital formation) (both in billions of constant 2011 international dollars) and on the gross domestic product (in billions of constant 2011 international dollars) for the LAC countries from the "*Investment and Capital Stock Dataset*" by the IMF (2017). The blue line represents the mean of public investment (% of GDP) (IPUB_mean), and the orange line the mean of private investment (% of GDP) (IPRIV_mean). LAC countries included: Antigua and Barbuda, Argentina, The Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Uruguay, Venezuela.

Figure 2.4 – Public investment and private investment (% of GDP) – LAC (1970-1979)

In fact, according to Henderson et al. (2000), during this decade, the regional governments (as also private enterprises) contracted large-value loans from several commercial banks and international lending institutions, mostly for infrastructure development, with the purpose of industrialising their economies. This strategy made the LA countries' external debt grew at a remarkable rate of 27% per year (Grosse and Goldberg, 1996).

The borrowing level increased even more with the oil price shocks (particularly after the 1973 oil crisis and the 1973–1975 world recession), which brought commodity prices down. Following the graph from Figure 2.4, public investment grew shortly after 1973 (possibly due to the borrowed money). Nevertheless, there were many physical capital investments that were poorly planned (with low social rates of return), especially in the public sector, and that ended up being largely inefficient (World Bank, 1995).

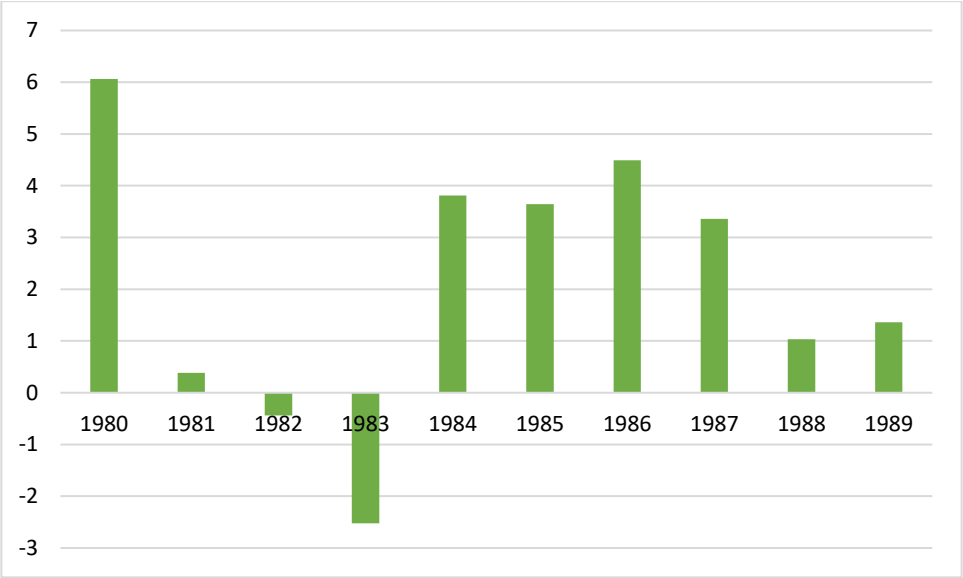
As one could expect, this borrowing strategy quickly displayed signs of not being sustainable. With the worldwide economic slowdown, the rise in the global interest rates and debt services, and with the emergence of another energy crisis in 1979, the LAC region was preparing to enter the decade that became known as “the lost decade”.

2.3 Physical Capital in Latin America and the Caribbean: 1980s

When entering the 1980s decade, the LAC region saw its macroeconomic condition deteriorate, primarily due to the negative effects of its debt-service problems. The countries from this region register large deficits in their balance of payments and problems related to their high inflation and unemployment (stagflation). Still, even with the signs that the region's economy was getting into some severe difficulties, LAC governments continued to borrow. They saw this negative situation as temporary.

Additionally, the region’s poorly accomplished economic policy, characterized by shy progress in structural policies (e.g. in the provision of public infrastructure) and failed stabilization policies, also contributed, in a great deal, to increase the pressure associated with these countries debt and to the deteriorate, even more, their macroeconomic condition (Loyaza et al., 2005). When these facts were combined with the effects from external shocks (for which the LAC region is still very prone), the situation became even more worrisome. The results were a significant drop in investment and domestic savings and a large capital outflow (i.e. capital flight) (Atkins, 1999).

As it could be expected, this nefarious environment led to a huge drop in the regional growth rates. As it can be seen in Figure 2.5, the LAC went from a GDP growth (annual %) of 6% in 1980 to more or less than 0.4% in 1981, reaching negative growth rates in the years that followed (1982, 1983).



Notes: This graph was created by the author and was based on GDP growth (annual %) data for the LAC aggregate from the World Bank "*World Development Indicators*" database.

Figure 2.5 – GDP growth (annual %) – LAC (1980-1989)

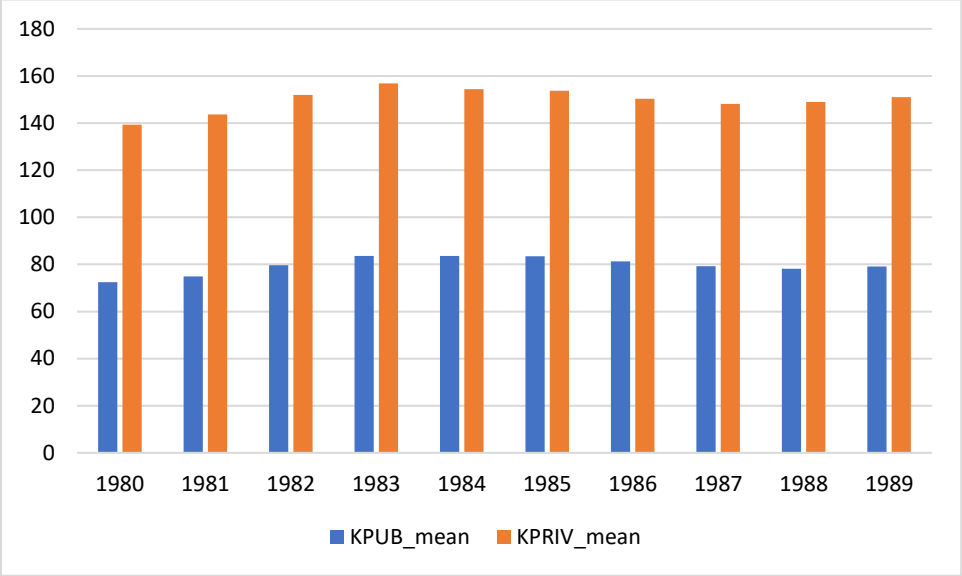
In order to tackle inflation, at the beginning of the 1980s, the United States (US) increased their interest rates. This placed the LAC countries in a tangled situation. Due to their already high debt levels, the increase in debt service payments led to a situation where they could not repay their debt. When they were unable to contract more loans, they started to face the reality that they would not overcome their debt servicing problem.

Mexico was the first to declare that it could no longer meet its external debt-servicing obligations, entering a situation of sovereign default in 1982. After a brief period, several other LAC countries officially announced that they were also incapable of paying back their debt, thus turning the LAC debt problem into a debt crisis.

In order to overcome this situation, some changes started to be made in the LAC economic policy during the 1980s and 1990s. There was an implementation of a series of reforms focused on economic stabilisation and on the privatisation and liberalisation of their economies. This set of reforms, which were largely sponsored by the United States Treasury, the IMF, and the World Bank, were later denominated as the "*Washington Consensus*" (Williamson, 1990).

With all this in mind, one can now see the LAC public and private capital evolution in the 1980s. Looking at Figure 2.6, the public and private capital stock as a percentage of GDP presented a positive evolution until 1983, where they have achieved 83.6% and 156.8%

of GDP, respectively. Even though these shares seem to have decreased in the following years, overall, they were higher than in the 1970s decade.

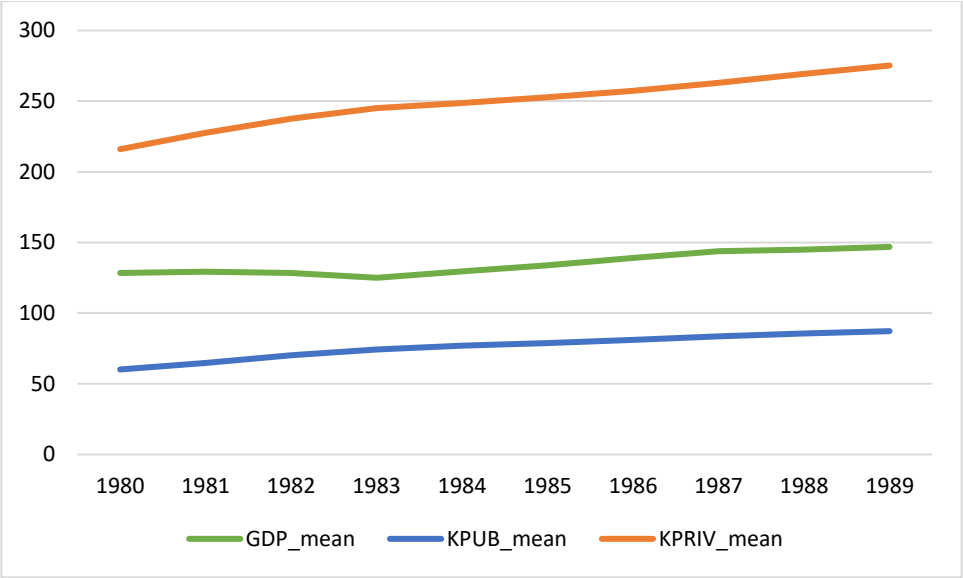


Notes: This graph was created by the author and was based on the data for general government capital stock and private capital stock (both in billions of constant 2011 international dollars) and on the gross domestic product (in billions of constant 2011 international dollars) for the LAC countries from the "*Investment and Capital Stock Dataset*" by the IMF (2017). The blue bars represent the mean of public capital stock (% of GDP) (KPUB_mean), whereas the orange bars are the mean of private capital stock (% of GDP) (KPRIV_mean). LAC countries included: Antigua and Barbuda, Argentina, The Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Uruguay, Venezuela.

Figure 2.6 – Public capital stock and private capital stock (% of GDP) – LAC (1980-1989)

However, these higher shares may be related to some negative features rather than to greater investment. As can be seen in Figure 2.7, where the public capital stock, private capital stock, and gross domestic product are displayed in billions of constant 2011 international dollars, there was an increase in both types of capital stock during this decade. This is expectable given that public and private capital as a stock rarely decrease.

Nevertheless, in the 1980s decade, the regional GDP registered a poor performance, especially when compared with the results from the previous decade. In fact, the LAC region reached negative growth rates in 1982 and 1983. This means that the increases of both public and private capital stocks as a percentage of GDP can probably be mainly attributed to the regional GDP decrease rather than the increase of the LAC investment levels.



Notes: This graph was created by the author and was based on the data for general government capital stock and private capital stock (both in billions of constant 2011 international dollars) and on the gross domestic product (in billions of constant 2011 international dollars) for the LAC countries from the "*Investment and Capital Stock Dataset*" by the IMF (2017). The blue bar represents the mean of public capital stock (KPUB_mean), the orange bar the mean of private capital stock (KPRIV_mean), and the green bar the mean of gross domestic product (GDP_mean). LAC countries included: Antigua and Barbuda, Argentina, The Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Uruguay, Venezuela.

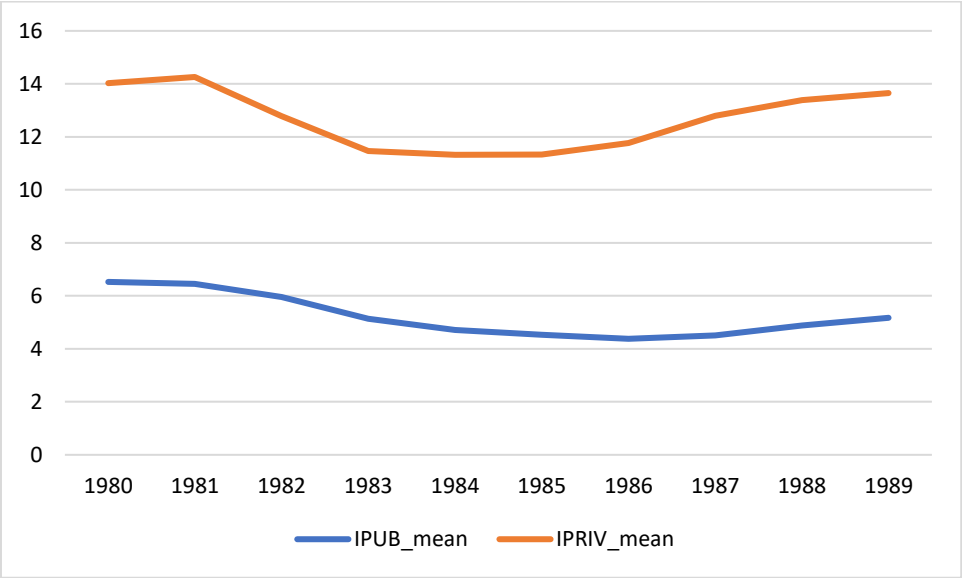
Figure 2.7 – Public capital stock, private capital stock, and GPD (in billions of constant 2011 international dollars) – LAC (1980-1989)

To reinforce the previous idea, one can now look at Figure 2.8, where it is presented the LAC public and private investment evolution (both as a percentage of GDP) between 1980 and 1989. Through the graph from Figure 2.8, it is clearly seen that, in the 1980s, the LAC region suffered from a break in both public and private capital investment.

When looking at the region's economic situation in that decade, it easy to explain why the region experienced such breaks. First, it can be held that in order to pursue fiscal consolidation, i.e. to control their deficits and debts, the LAC governments decided to make some serious cuts on their expenditures and, subsequently, reduce their public investment levels, namely on infrastructure projects (Birdsall et al., 2010).

Second, as it was previously referred, due to the emergence of the debt crisis and the LAC economic instability, a significant number of foreign private investors decided to move

their investments to regions whit better economic perspectives. This led to a situation of massive capital flight in LAC (Harris and Nef, 2008).



Notes: This graph was created by the author and was based on the data for general government investment (gross fixed capital formation) and private investment (gross fixed capital formation) (both in billions of constant 2011 international dollars) and on the gross domestic product (in billions of constant 2011 international dollars) for the LAC countries from the "*Investment and Capital Stock Dataset*" by the IMF (2017). The blue line represents the mean of public investment (% of GDP) (IPUB_mean), and the orange line the mean of private investment (% of GDP) (IPRIV_mean). LAC countries included: Antigua and Barbuda, Argentina, The Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Uruguay, Venezuela.

Figure 2.8 – Public investment and private investment (% of GDP) – LAC (1980-1989)

As it could be expected, the reduction in both public and private investment hampered the LAC development and growth, increasing the gap between this region and their main competitors, such as the countries from East Asia (EA) (UN, 2017; Ramirez and Nazmi, 2003; Pastor, 1990). Indeed, the infrastructure gap of the region started to become more and more notorious. This is especially true if one compares the infrastructure levels from the LAC in the 1980s with the ones from similar developing regions (as the EA) in the same decade (Easterly and Servén, 2003).

Due to the notable deterioration of the LAC economic situation, it became clear that some considerable efforts should be made in order to improve the region's economic condition and to put it back on the path of growth and development. At the end of the 1980s and

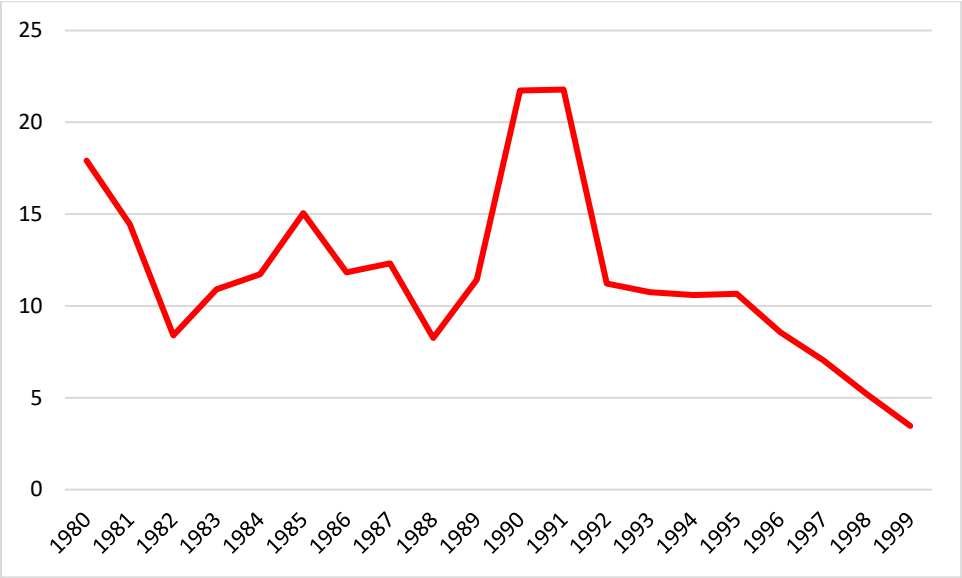
the beginnings of the 1990s, the region's governments continued to follow the path to a more open regional economy, with a series of market-orientated reforms.

As an example, in 1989, the "*Brady plan*" was introduced in the LAC region to support the region's macroeconomic restructuring. Basically, this was a debt restructuring plan stating that if the LAC countries continued with the market liberalisation reforms, they would reduce their debts and not be excluded from the international capital markets and new funding (Frenkel, 1989). In the following section, the results from this strategy will be appraised, as also the effect that it had on the LAC public and private capital in the 1990s.

2.4 Physical Capital in Latin America and the Caribbean: 1990s

Even though the reforms started to be introduced in the LAC region in the 1980s, it was in the following decade that the LAC strongly embraced the guidelines from the "*Washington Consensus*" and from the "*Brady Plan*". In the 1990s, the LAC governments adopted a series of reforms to promote macroeconomic stabilisation and to increase the outward orientation and the market orientation of their economies (Birdsall et al., 2010).

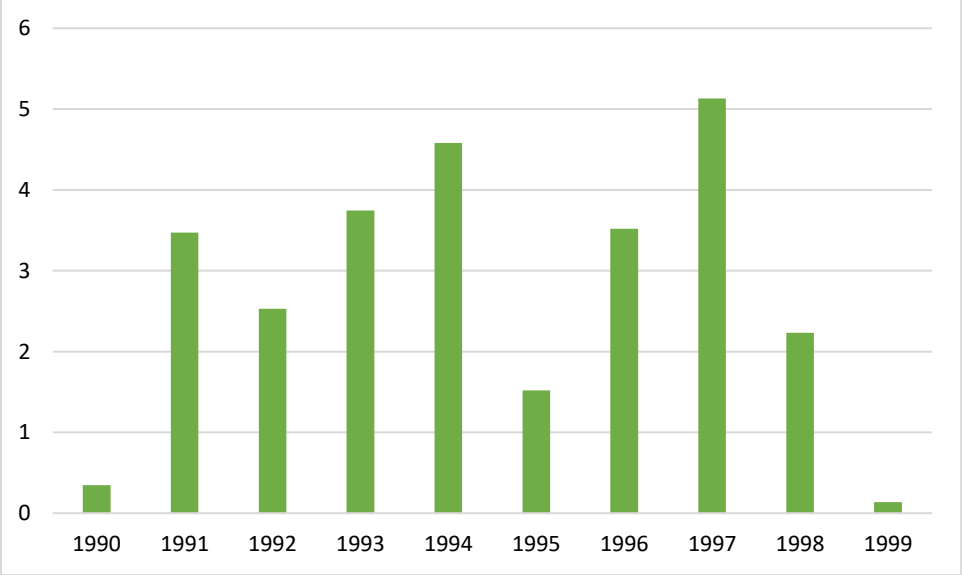
Due to these structural reforms, the LAC was able to control its high inflation problem (Figure 2.9) and improve its macroeconomic condition (Figure 2.10). In addition, the reforms which were conducted also led the private investment to return to the LAC region (Birdsall et al., 2010).



Notes: This graph was created by the author and was based on inflation, consumer prices (annual %) data for the LAC aggregate from the World Bank "*World Development Indicators*" database.

Figure 2.9 – Inflation, consumer prices (annual %) – LAC (1980-1999)

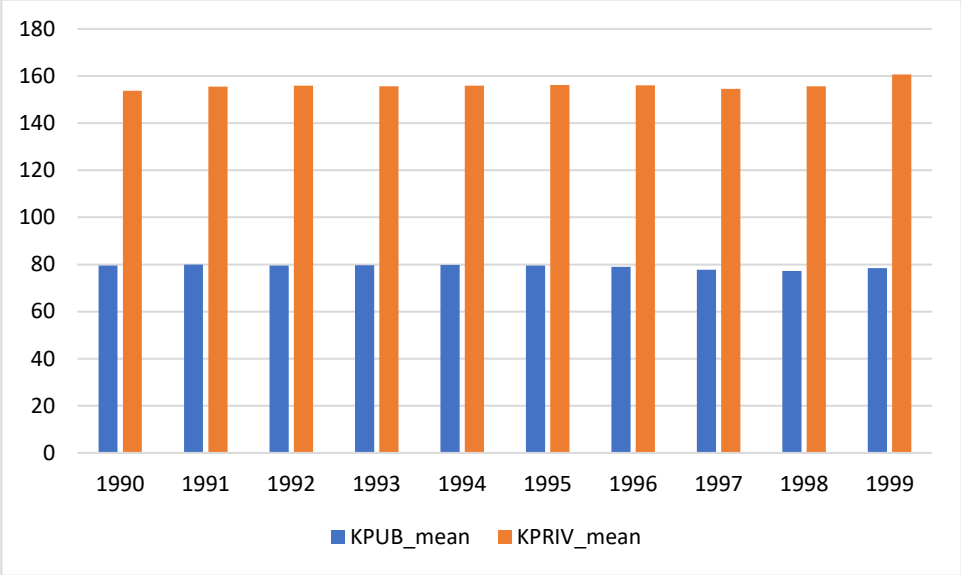
As it can be seen in Figure 2.10, in the 1990s, the LAC region registered an improvement in its growth rates compared with the previous decade. This improvement was mostly felt by the countries that conducted the economic stabilization reforms, being primarily generated through the progress in the LAC total factor productivity (TFP) than to the human and physical capital accumulation (Loayza et al., 2005).



Notes: This graph was created by the author and was based on GDP growth (annual %) data for the LAC aggregate from the World Bank "*World Development Indicators*" database.

Figure 2.10 – GDP growth (annual %) – LAC (1990-1999)

Looking at Figure 2.11, in the 1990s, the evolution from both public and private capital stocks as a percentage of GDP was, once again, quite flat. Public capital stock was always around 79% of GDP, a level similar to that of the late 1980s, whereas private capital stock was always around 156% of GDP, a value comparatively higher than that of the previous decade. Given the positive growth rates of the LAC in the 1990s, it could be that this time the increase in private capital stock as a percentage of GDP was registered through the rise in private investment.



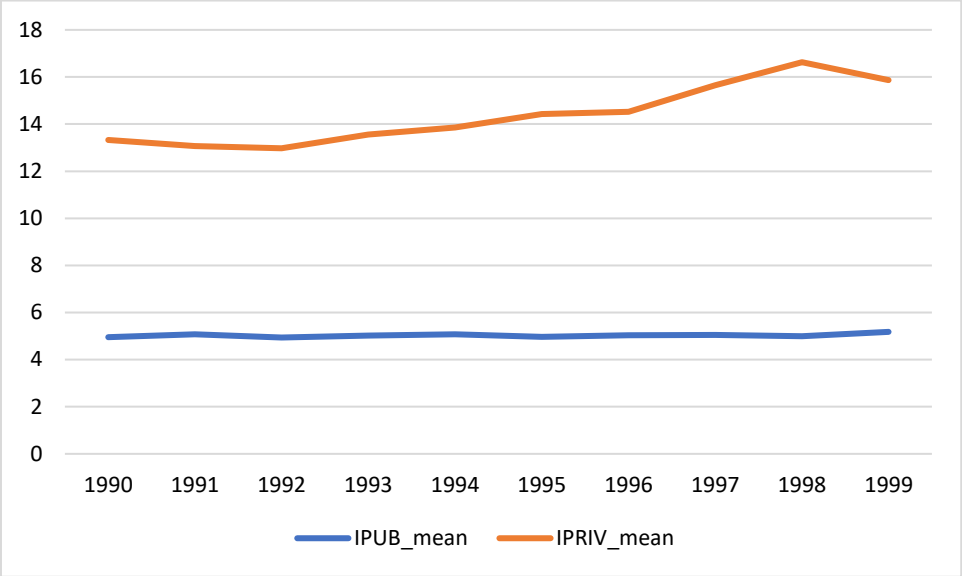
Notes: This graph was created by the author and was based on the data for general government capital stock and private capital stock (both in billions of constant 2011 international dollars) and on the gross domestic product (in billions of constant 2011 international dollars) for the LAC countries from the "*Investment and Capital Stock Dataset*" by the IMF (2017). The blue bars represent the mean of public capital stock (% of GDP) (KPUB_mean), whereas the orange bars are the mean of private capital stock (% of GDP) (KPRIV_mean). LAC countries included: Antigua and Barbuda, Argentina, The Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Uruguay, Venezuela.

Figure 2.11 – Public capital stock and private capital stock (% of GDP) – LAC (1990-1999)

Looking at Figure 2.12, this seems to be the case, given that private investment in LAC appears to have grown from 1992 to 1998, only decreasing again in 1999. As previously explained, this positive trend in private investment in the 1990s can be mainly linked with the structural reforms conducted in the LAC region in the first half of the decade.

These reforms promoted the liberalisation of the LAC economies and encouraged the privatisation of several State enterprises, consequently allowing the re-entry of private

capital inflows into the region. As an example, it can be stressed the infrastructure sector case where, between 1990 and 1998, private investment went from $10 billion to more than $70 billion, following the opening of this sector to privatisation (Calderón and Servén, 2010, p. 29).



Notes: This graph was created by the author and was based on the data for general government investment (gross fixed capital formation) and private investment (gross fixed capital formation) (both in billions of constant 2011 international dollars) and on the gross domestic product (in billions of constant 2011 international dollars) for the LAC countries from the "*Investment and Capital Stock Dataset*" by the IMF (2017). The blue line represents the mean of public investment (% of GDP) (IPUB_mean), and the orange line the mean of private investment (% of GDP) (IPRIV_mean). LAC countries included: Antigua and Barbuda, Argentina, The Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Uruguay, Venezuela.

Figure 2.12 – Public investment and private investment (% of GDP) – LAC (1990-1999)

However, from Figure 2.12, one can see that contrarily to the private investment, public investment remained almost constant from 1990 to 1999. This fact can be mainly attributed to the already referred fiscal consolidation and economic stabilization strategies followed by the LAC governments in this decade, which led to significant government expenditure cuts.

Despite the positive trend in private investment and the considerable impact that it had on the telecommunications and energy areas, it seems that it did not manage to compensate public investment cuts in other areas, as for example, in infrastructure provision (Rozas, 2010). This can be possibly attributed to the fact that the private

initiative has primarily invested in higher-income and/or lower-risk sectors (ECLAC, 2002).

Again, when the evolution of infrastructure development in LAC countries is compared with their Asian competitors, fundamental differences reappear. Despite the important role that privatisations had in the LAC in this decade, the Asian countries had a larger amount of foreign investment directly linked to new physical capital, also called greenfield investment (Faruqee, 2016). In fact, the LAC infrastructure gap relative to the EA countries grew considerably between 1980 and 1997 (Fay and Morrison, 2007).

Although the apparent economic recovery of the region, at the turn of the millennium, the Asian financial crisis (which started in 1997) rapidly spread its effects to the LAC. Together with the failure of the 1990s reforms to promote sustainable growth and improve living standards, this situation led several LAC countries to go back into difficulties (with many of them entering a recession path).

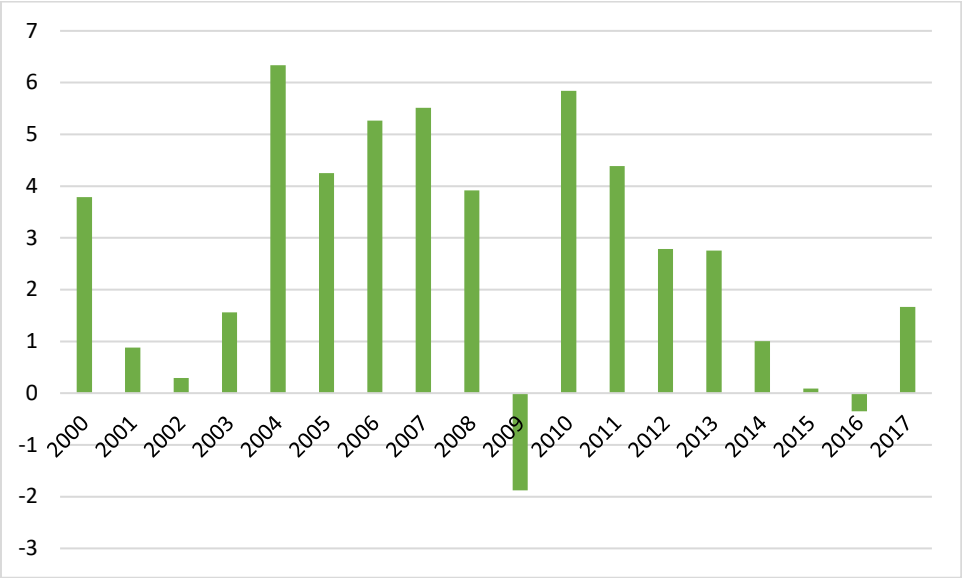
As it can be seen in Figure 2.10, the signs that something was wrong were already being felt in the final years of the 1990s, with the growth rate of the LAC region being only 0.14% in 1999. In the following section, it will be seen how the LAC countries overcame this situation and how the region's economy evolved from 2000 to 2017 and will be analysed what happened to public and private capital in this region during this same period.

2.5 Physical Capital in Latin America and the Caribbean: New Millennium (2000-2017)

Regardless of the reforms that were implemented in LAC in the 1990s and despite the fairly good growth rates that the region was able to achieve in the first half of this same decade, the LAC economy continued to suffer from a high degree of volatility, especially due to the effects from external shocks. Looking back, it is almost consensual that more efforts could have been made in order to reduce this volatility. This is because this problem has continued to hamper the region's growth rates, increase the region's poverty and inequality, and reduce the region's capacity to invest in infrastructure and human capital (Birdsall et al., 2010).

An example of the impact of external shocks is the previously referred case of the Asian financial crisis (1997), whose adverse effects were rapidly extended to the LAC. In the late 1990s, several countries in the region went into recession, a situation which was

aggravated by the banking and currency crisis that arose in some of the biggest LAC countries (e.g. in Brazil (1998-1999) and Argentina (2001-2002)).

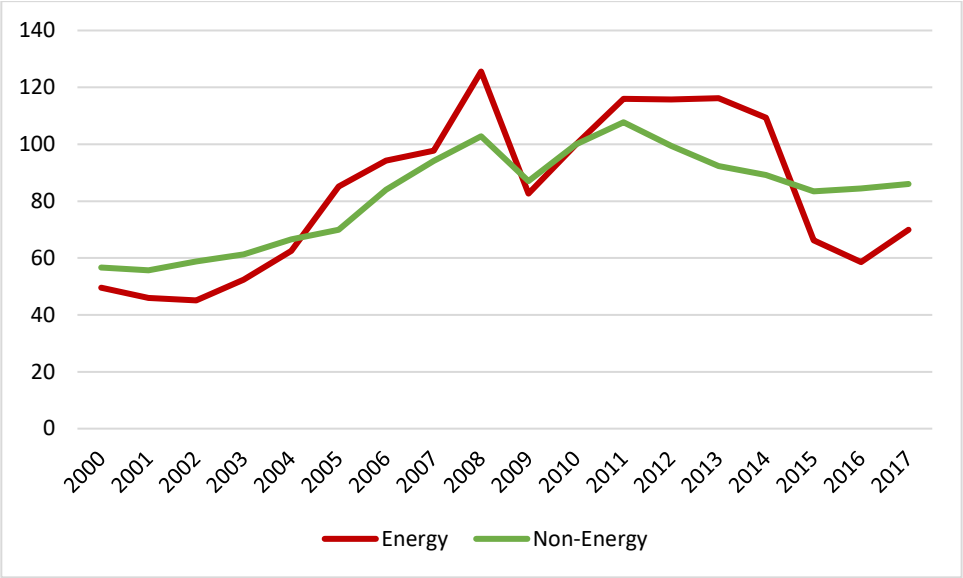


Notes: This graph was created by the author and was based on GDP growth (annual %) data for the LAC aggregate from the World Bank "*World Development Indicators*" database.

Figure 2.13 – GDP growth (annual %) – LAC (2000-2017)

When LAC governments feared they were entering into another "*lost decade*", a phenomenon changed that perspective: the "*2000s commodities boom*". Due to a combination of high commodity prices with the boom in international trade, the improvement in financing conditions and the increase in the volume of remittances, the LAC experienced a period of growth that was only comparable to that of the 1970s (Ocampo, 2009).

As it can be seen in Figure 2.13, the LAC region entered economic recovery between 2003 and 2007, achieving a sequence of respectable growth rates. However, in 2008, they shrunk again, mostly due to the global financial crisis, which pushed the commodity prices down (see Figure 2.14). Contrary to the expectations, after the hit of the financial crisis and the subsequent drop in commodity prices, the LAC was managed to recover quickly. In 2010, the regional growth rate was already at pre-2008 levels (see Figure 2.13).



Notes: This graph was created by the author and was based on energy and non-energy commodity price index (annual indices, 2010 = 100, real 2010 US dollars) data from the "*World Bank Commodity Price Data (The Pink Sheet)*" from the World Bank. The red line represents the index values for energy commodity prices (Energy), and the green line represents the index values for non-energy commodity prices (Non-Energy).

Figure 2.14 – Energy and Non-Energy commodity price index – (2000-2017)

Additionally to the effects from the changes in the region's economic policy, which were able to convert these countries external shock amplification factors into shock absorbers (there was an improvement on the flexibility and credibility of their currencies, on the robustness of their public finances, and on the capitalization and liquidity of their banking systems), the increased connection between China and the LAC region during the 2000s also played an important role in this quick economic recovery (World Bank, 2011).

Moreover, in addition to the increased China-LAC trade and the increased Chinese investment in the LAC region, another factor (also from China) explains the economic recovery of LAC. In order to respond to the 2008 crisis, China launched a series of stimulus packages that prompted the international commodity prices to rise again (mainly due to their effect on the Chinese import demand) (Li et al., 2012).

However, looking at Figure 2.13 and 2.14, it can be seen that with the end of the "*2000s commodities boom*" in 2014 (together with the slowdown in the Chinese and United States economies), the LAC growth rates went back down, reaching a negative value in 2016 (-0.3%). Following a report from the Economic Commission for Latin America and the Caribbean (ECLAC), with the slowdown in the region's economic activity, in its GDP

per capita, in its investment levels, and its consumption and exports, the LAC may record the slowest growth of the last forty years in the 2014-2020 period (ECLAC, 2019).

After this review of the region's economic performance in the new millennium, the evolution of LAC public and private capital between 2000 and 2017 will now be analysed, starting with the progression of public and private capital stocks as a percentage of GDP (Figure 2.15).

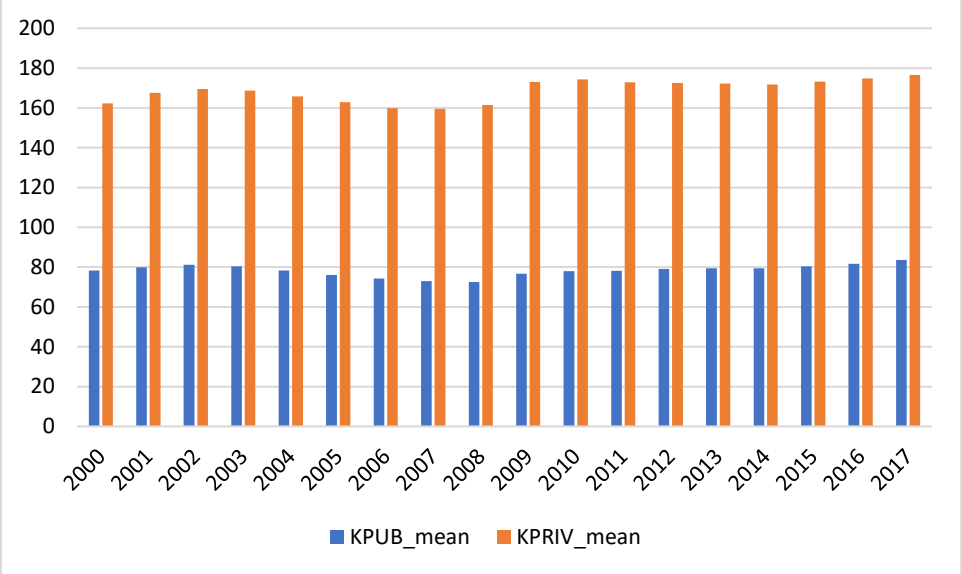


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Figure 2.15 – Public capital stock and private capital stock (% of GDP) – LAC (2000-2017)

As it can be observed in Figure 2.15, private capital stock as a percentage of GDP was, overall, higher than in the 1990s, increasing until 2002, decreasing from 2003 to 2007, and increasing again until 2009. Then, until 2017, it was nearly constant, being always around 173% of GDP.

Concerning public capital stock as a percentage of GDP, in general, the shares seem to be pretty much identical to those from the previous decade, except in the 2002-2003 and

2015-2017 periods, where public capital stock as a percentage of GDP exceeded the 80% of the GDP. Regarding its evolution, it can be seen that the LAC public capital stock as a percentage of GDP increased until 2002, decreased until 2008, and then increased again until 2017.

As in the previous case (Figure 2.6), the shares were higher in periods of economic slowdown, for example, in 2002 and 2009, and were lower in the period of relatively good economic performance. These once again raise doubts concerning the real physical capital investment in the LAC region. Hence, in Figure 2.16, one can see the public and private investment as a percentage of GDP between 2000 and 2017.

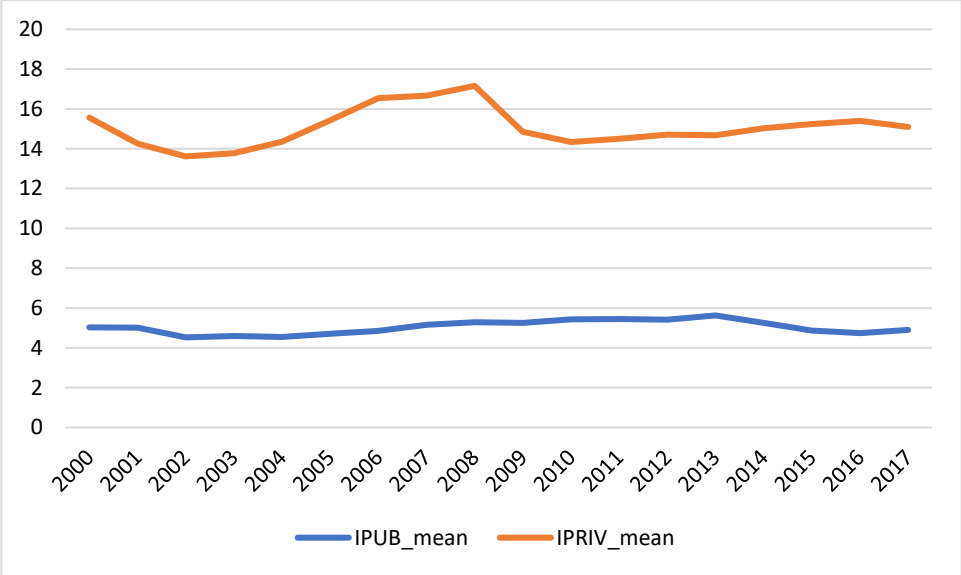

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Figure 2.16 – Public investment and private investment (% of GDP) – LAC (2000-2017)

Looking at Figure 2.16, it can be seen that, until 2002, there was a reduction in private investment as a percentage of GDP, mostly due to the adverse economic situation in LAC between 1998 and 2002, which discouraged investment by the private sector in this same

period. In the case of public investment as a percentage of GDP, it has also suffered a decrease in this period. However, the magnitude of this decrease was smaller than in the private investment case, mainly since the public investment was already far from ambitious levels in previous years.

Then, from 2003 until 2008, private investment grew again, reaching 17% of GDP (2008), when it contracted again until 2010 (due to the effects of the global financial crisis). After 2010, private investment went back up, and even though the commodity price boom ended in 2014, it only shrunk again in 2017.

Regarding public investment, it is noticed that after the decrease that occurred until 2002 followed by a stagnation until 2004, it grew again until 2013, although it was a moderate growth. It is important to refer that, since 2000, public investment was always around 5% of GDP (in some years with a slightly lower percentage and others with a slightly higher one). Even with the hit of the global financial crisis, it did not fall abruptly. It has only suffered a slight drop in 2009 (5.25%;), rising again in 2010 (5.43%).

In part, this fact can be justified by the gains that the LAC region got through from the commodity prices boom. It is considered that these gains improved these countries public finances and allowed the region's governments to develop countercyclical responses to the financial crises, namely with increased investment in public infrastructure (Lardé, 2016).

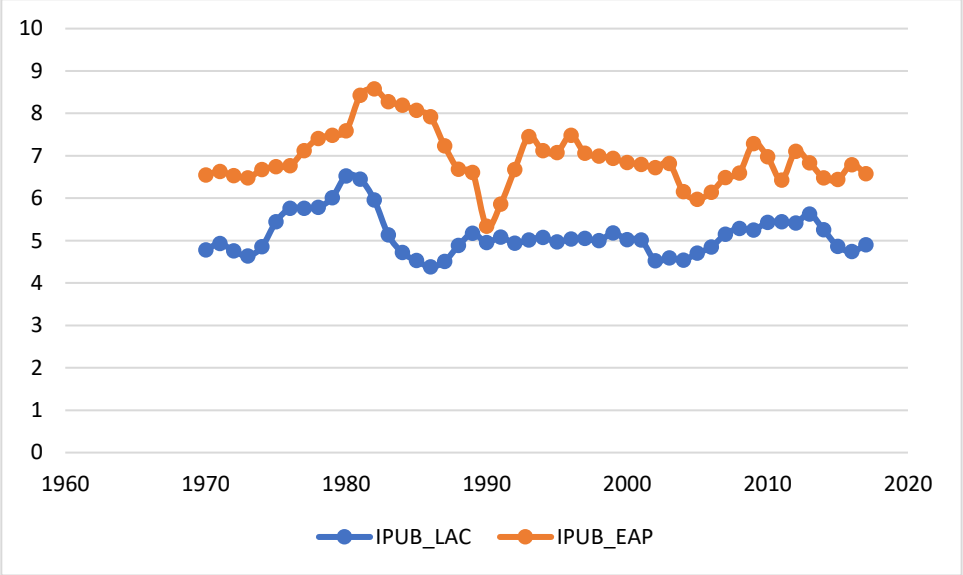
However, as it was already seen in Figure 2.15, the evolution of public and private capital stocks in the percentage of the GDP seems to point to the idea that public and private investment seems to be still far from the value that can guarantee the desired reduction of the LAC infrastructure gap. As it was previously referred, these shares seem to have been higher in periods of economic contraction (i.e. of decreased growth and investment) and lower in periods of economic expansion (i.e. increased growth and investment).

As an example, it can be seen that public capital stock as a percentage of GDP increased during the 2000-2002 period and decreased during 2003-2007 (more precisely, it went from 80% of GDP to 73%). This could mean that even though the public investment that was made between 2003 and 2007 (the first period of the commodity boom) was not proportional to the evolution of the GDP. In the end, the region was not able to maintain the public capital stock share of the 2000-2002 period (although this appears to have been largely influenced by the contraction of GDP rather than by an increase in investment). In the private capital case, a similar situation is noticed.

In general, the conclusion is that the LAC needs to increase its physical capital investment levels, because as Cavallo and Powell (2019, p. 97) stressed, "*Latin America and the Caribbean invests too little in infrastructure. Investment is low not only in comparison to other regions, it is also low in relation to the region's need to close large infrastructure gaps*".

2.6 Comparation with East Asia and Pacific and the Global Infrastructure Outlook data

Before proceeding to the conclusions, it could also be interesting to look at some additional data that could reinforce the previous assumptions regarding the low LAC physical capital investment levels. In this sense, one can start by presenting public investment data from the LAC and the EAP in Figure 2.17.



Notes: This graph was created by the author and was based on the data for general government investment (gross fixed capital formation) and the gross domestic product (both in billions of constant 2011 international dollars) for the LAC and EAP countries from the "*Investment and Capital Stock Dataset*" by the IMF (2017). The blue line represents the mean of public investment (% GDP) for the LAC (IPUB_LAC), and the orange line the mean of public investment (% of GDP) for the EAP (IPUB_EAP). LAC countries included: Antigua and Barbuda, Argentina, The Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Uruguay, Venezuela. EAP countries included: Cambodia, China, Indonesia, Korea, Lao P.D.R., Malaysia, Mongolia, Myanmar, Philippines, Singapore, Thailand, Vietnam.

Figure 2.17 – Public investment (% of GDP) mean for LAC and EAP – (1970-2017)

Looking at Figure 2.17, it is noted that the public investment from the LAC was always behind the one from the EAP, which can be one additional support to the idea that the

LAC indeed invests too little. Moreover, this is especially worrying given that this comparison was made with a similar developing/emerging region such as the EAP (one of the region's main competitors).

To reinforce, once again, the necessity to increase the physical capital investment in LAC, Table 2.1 presents the infrastructure investment needs and gaps of some LAC countries up to 2040 following data from the "Global Infrastructure Outlook". The "Global Infrastructure Outlook" is an initiative from the Global Infrastructure Hub (a G20 organisation) and Oxford Economics which analyses the countries' current investment trends and needs and produces an estimate of their investment gap.

Table 2.1 – Infrastructure investment gap

	All Sectors	Energy	Tele-communications	Transport: Airport	Transport: Ports	Transport: Rail	Transport: Road	Water
Argentina	$358 B	$39 B	0	$833 M	0	$15 B	$302 B	$1 B
Brazil	$1.2 T	$109 B	$17 B	$31 B	$71 B	$102 B	$852 B	$7 B
Chile	$53 B	$6 B	$8 B	$886 M	$3 B	$35 B	$65 M	$20 M
Colombia	$100 B	$10 B	$5 B	$2 B	$5 B	$497 M	$75 B	$1 B
Ecuador	$55 B	$6.1 B	$1.9 B	$1.2 B	$1.5 B	$4.6 B	$40 B	$228 M
Mexico	$544 B	$39 B	$19 B	$3.4 B	$2.7 B	$14 B	$464 B	$1.6 B
Paraguay	$17 B	$12 B	$1 B	$2.7 B	0	$1.4 B	0	$31 M
Uruguay	$10 B	$2.7 B	$2.1 B	$289 M	$687 M	$3.7 B	$27 M	0

Notes: This table was constructed based on the data from the "*Global Infrastructure Outlook*" of the Global Infrastructure Hub and the Oxford Economics (https://outlook.gihub.org); T, B, and M represent trillion $US, billion $US, and million $US, respectively.

Among the 56 countries included in the "Global Infrastructure Outlook", eight are from the LAC. They are Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, and Uruguay. As it can be perceived by looking at the data displayed in Table 2.1, these countries will need to make a significant effort to close their investment gap. Looking only at Brazil (the country with the biggest investment gap), it will need to invest 1.2 trillion $US more up to 2040, considering its current investment trend.

2.7 Conclusion

From this analysis, it was seen that, first, the LAC economic performance (and economic strategies) has always been affected by the booms and busts resulting from the effects of external shocks. As it could be perceived, since 1970, the LAC region went into periods where it experienced relatively high growth rates (as the 1970s, the first half of the 1990s, and during the commodity boom that went from 2003 until 2014) and periods in which it went into recession and economic depression (as the "*lost decade"* of 1980s, and the period between 1998 and 2002).

That said, looking at the evolution of public and private capital in the LAC region between 1970 and 2017, it is unsurprising that the economic situation of the LAC has always influenced this evolution in each one of these periods. In fact, it was seen that in the 1970s, a decade of economic prosperity, the LAC countries tried to increase their public and private capital.

Although it is considered that this effort could have been greater (especially given that the plan was to increase the degree of industrialisation of the region), it must be kept in mind that, in that decade, the State had a significant weight in these economies and the LAC governments investment strategies were primarily based in large-value loans from diverse commercial banks and international lending institutions. Due to this, a greater investment level would always have to be accompanied by several structural changes in these economies.

Particularly, they would have to make some changes regarding their financing methods. Indeed, because of their borrowing strategy, these countries external debt grew at an impressive rate at the time. As one could expect, this strategy was not sustainable. With the slowdown of the world economy, with the increase in the global interest rates and the debt services, and with the emergence of the 1979 energy crisis, LAC countries saw their macroeconomic condition deteriorate in the 1980s. The result was the region's entry into a debt crisis.

Due to the crisis, there was a sharp drop in the LAC public and private capital investment in the 1980s. In this decade, LAC governments significantly reduced their spending while there was also an exodus of private capital from the region. Given the deterioration of the LAC economies, the regional governments conducted a serious macroeconomic restructuring to reverse this situation and pursue the region's economic stabilisation.

With a series of reforms focused on the increase of the outward orientation and the market orientation of these economies, the LAC was able to control their high inflation problem, achieve better growth rates and once again attract private capital to the region in the 1990s. Nevertheless, although private investment has grown considerably during this period, the level of public capital investment continued to be rather low, mainly due to the macroeconomic stabilisation and fiscal consolidation strategies that have been adopted.

At the end of the 1990s and the beginning of the 2000s, the LAC region saw their economy contract again, with several LAC countries entering a recession path. With a

growing disappointment regarding the results from the reforms which were implemented, the region went again into a tough period and saw, once again, a reduction in its investment, especially in the private capital case.

Due to the commodity prices boom in 2003, the LAC entered again into economic recovery. It underwent a period of good economic growth rates until the emergence of the global financial crisis in 2008. Public and private investment also accompanied the region's economic recovery. After the crisis struck the region, private investment dropped once again, but the public investment did not follow the same path. Due to the LAC governments countercyclical strategies, public investment was not reduced. In fact, it increased (slowly) until 2013.

Looking at its growth rates, it can be considered that the LAC was able to overcome the crisis in a relatively short period. Some of the reasons for these are the high commodity prices and the increased connection between this region and China. With the end of the commodity prices boom around 2014, the LAC public investment decreased once again. The LAC private investment, which increased again after 2010, continued to follow a growing trend but failed to reach the pre-crisis levels again.

In general, it can be concluded that between 1970 and 2017, regional public investment was always relatively low. It was always between 4% and 6% of the GDP. In fact, it has only have passed the 6% of GDP on rare occasions, namely in 1979, 1980, and 1981. Concerning the LAC private investment, it was much more volatile, with larger peaks and breaks than the public investment. In other words, it seems that it was more sensitive to the economic situation of the LAC in each one of the periods which were analysed.

Discussing the evolution of public and private capital stocks as a percentage of GDP between 1970 and 2017, it can be said that, in the analysis which was conducted, it was noted that both stocks have increased during this period. However, this positive evolution was actually very slow and, in some decades, it was almost constant.

These facts raise some doubts on the capacity of the LAC to invest in new physical capital, a suspicion which is reinforced by the fact that some of the highest shares were registered in years of economic slowdown. This situation can be quite worrying, given that it is believed that the lack of physical capital investment in LAC can lead to several negative effects on the region's economies and, consequently, hamper the region's growth, development, and competitiveness.

Among the several positive effects that the provision of physical capital (as, for example, infrastructure) can have is that it usually considered as an essential factor to connect areas, populations and businesses, contributing to enhancing a country/region economic dynamism and to a more territorially balanced economy, with increased economic opportunities for both people and productive fabric. Moreover, it can also positively impact human capital and contribute to increasing the equality in access to education and health with, for example, the construction of social infrastructure (e.g. schools and hospitals).

Due to all this, it is natural that the lack of physical capital investment in LAC may negatively affect the region. This because this lack of investment does not allow these positive effects to be materialised in the regional economy. In addition, it should also be stressed that this situation can also affect the region's investment absorption mainly because private initiative prefers to invest in countries/regions with a satisfactory supply of infrastructure, allowing them to conduct their activities without further limitations and reduced costs.

Given the conclusions from this analysis, it is essential that the LAC governments increase their public investment levels in physical capital, namely in infrastructure, in order to be able to promote the region's development. However, this investment must be very well planned and properly managed and cannot be based on the debt strategy which was followed in the 1970s.

Additionally, they also need to make some effort in order to reduce the volatility of the private investment. There is a need to develop measures in order to avoid the massive capital flight in times of economic downturn. It should not be forgotten that the private sector can also be a help to guarantee a sufficient level of physical capital investment in countries with major public financing problems.

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Chapter 3

The relationship between public capital stock, private capital stock, and economic growth in Latin America and Caribbean countries

In this chapter, the relationship between public capital stock, private capital stock, and economic growth was analysed for a group of 30 Latin America and Caribbean countries from 1970 to 2014. The panel vector autoregression (PVAR) methodology, the panel dynamic ordinary least squares (PDOLS), and the panel fully modified ordinary least squares (PFMOLS) estimators were used to achieve the goals of this analysis. The results from the estimations point out that both public and private capital have had a positive effect on the long-run economic growth of the countries from the sample. However, the results also point to that in the short-run, public capital seems to crowd-out private capital, which, consequently, could be one of the explanations for the adverse effect that public capital stock seems to have on growth in the short-run. These findings suggest that the Latin American and Caribbean governments should continue to support public and private investment projects, given the positive effect that both types of capital seem to have on the long-run economic growth of these countries. However, some changes should be made in the planning and execution of such investments in order to avoid some undesirable effects that seem to exist, especially in the short-run.

3.1 Introduction

One of the primary goals of governments around the world is to ensure that their countries achieve a sustainable economic growth path. In this sense, many studies have been produced to understand the effects of a vast number of variables on growth. The purpose of these studies is essential to help policymakers in developing appropriate growth strategies.

Within the extensive literature on this field, there are many relationships that should be intensely studied. One example is the relationship between public investment and economic growth. Although most economists agree on the vision that public capital stock has a positive effect on a country's economic output, some scholars are more sceptical regarding this positive effect.

There is no doubt that public capital stock is essential to a country's economic activity. Some examples of its positive effects are that it increases the aggregate output, enhances the economy's physical and financial resources, reduces private sector costs (Erden and Holcombe, 2006), contributes to the advancement and maintenance of human capital (Ramirez and Nazmi, 2003) and contributes to higher long-run growth and an increase in the aggregate demand in the short-run (Barbiero and Darvas, 2014).

However, even though countries need roads, airports, schools, and hospitals (among others) to grant a sound and sustainable economic performance, some factors may lead public investment to have a biased effect on the economy. For a public investment to obtain good results (i.e. raise a country's output level), economists should take into account the degree of economic slack and monetary accommodation of the countries, their investment efficiency (public investment management) and how they will finance the public investment (IMF, 2014).

The most apprehensive views point to the distorting effects that higher taxes (associated with public investment financing) can have on growth as a reason for governments to be more cautious with their expenditures (Fisher and Turnovsky, 1998). Additionally, some authors also stress the small macroeconomic multiplier of public investment as another reason not to increase public investment (Perotti, 2004). Overall, it must be kept in mind that the means that the governments use to finance public investment can, undoubtedly, affect a countries' general macroeconomic stability.

In fact, unsustainable means of financing can directly affect capital formation. Following Liaqat (2019), public debt can produce undesired effects on capital formation due to a crowding-out effect of debt on investment. However, this effect seems to be lower in high-income countries.

Moreover, the effect of public capital on growth can also depend on the relationship between public and private capital. If they act as substitutes instead of complements and compete with each other, it can generate a crowd-out effect on investment in the private sector (Erden and Holcombe, 2006).

Additionally, there is also the case of the law of diminishing returns. According to this law, the effects of the increase in public investment on economic growth can also depend on the existing capital stock. Following Romp and De Haan (2007; p. 9): "*an increment to the public capital stock would have a small (large) output effect if the capital stock in the previous period was large (small)*".

Following the International Monetary Fund (IMF) report "*Is It Time for an Infrastructure Push? The Macroeconomic Effects of Public Investment*" (IMF, 2014), in the last 30 years, public capital stock as a share of output has declined significantly worldwide. This led to a situation where infrastructure levels of developing countries are still far from the levels of the countries considered advanced. However, as these countries develop, their necessity for public investment increases.

Despite the possible positive effects that public investment would have on developing countries' growth, their high public debt and lack of investment efficiency make it advisable to weigh several factors before advancing with public investment programs. Moreover, it should be considered that the pressure surrounding public investment strategies in these countries has increased with a substantial number of failed projects in the past (Gupta et al., 2014).

Given these last statements, it becomes increasingly important to investigate the effects of public capital stock on the economic growth of countries such as those in the Latin America and Caribbean (LAC) region. The results from such empirical studies can shed some light on the macroeconomic effects of public investment in these countries and help their policymakers to draw up growth-promoting strategies. More importantly, they can help to ensure that past mistakes will not be repeated.

With respect to the sample of this chapter, it can be said that after the debt crisis of the 1980s, the LAC countries suffered from an intense depression that negatively affected various economic aspects of the region. One of these aspects was public investment, which was increasingly reduced. All public expenditure was reduced in accordance with the drastic economic adjustment and stabilisation programs implemented in the region to overcome the crisis effects.

The results from Ramirez and Nazmi (2003), who analysed nine Latin American (LA) nations in the period 1983–1993, are evident: both public and private capital contribute to economic growth. In fact, following their conclusions, it seems that the excessive reduction in both private and public investment is detrimental to economic growth.

The previous result seems to support the idea that maybe the chosen plan (a cut in government expenditure) was not the most appropriate. It should be considered that maybe these countries should have improved some other factors, as investment efficiency, instead of just reducing their investment levels.

More recently, according to the report "*Regional Economic Outlook, April 2016, Western Hemisphere Department: Managing Transitions and Risks*" (Faruqee, 2016), LAC competitiveness seems to be compromised by the state of the regional infrastructure. In fact, it seems that there is the risk that the infrastructure shortfalls gradually hamper the region's growth.

Following Faruqee (2016), the region should improve public investment management processes and practices and put some additional effort into maintaining the existing infrastructures. Moreover, the report also highlights the fact that both fiscal policy and fiscal institutions should play a serious role in this progress.

There are some additional studies related to the LAC "*infrastructure gap*" which should also be mentioned, like those by Castellani et al. (2019), Ruiz-Nuñez and Wei (2015), and Fay (2000). In general, the results of these studies point to the fact that there is indeed a lack of public investment in the LAC region.

Overall, these authors state that to close its identified "infrastructure gap", their governments should make some additional effort, i.e. they should increase their spending. In some situations, the strategy can start with the improvement in existing infrastructures rather than start investing in new infrastructure. However, this situation will need to be accompanied by the development of sustainable financing methods and strategies.

Despite the idea that more significant public investment is needed to overcome this gap, further research is required to realise what are the costs and benefits of increased public investment in the LAC countries. Indeed, it is necessary to investigate whether the increase in public investment will benefit the long-term and short-term growth of this region or if, alternatively, it will hurt these economies?

In this sense, this chapter will try to empirically answer these questions in order to be able to help LAC governments in the development of their public investment policies. The central question is then: what are the effects of public capital stock and private capital stock on the economic growth of the LAC countries? Furthermore, given the methodologies used in this chapter, some additional links between these three variables will also be explored.

Finally, this chapter is organised as follows: Section 3.2 presents an overview of the past literature that addresses the chapter's thematic and their respective conclusions; Section 3.3 describes the data and methodology used in this chapter; Section 3.4 shows both the

empirical results of the estimations and their subsequent discussion; Section 3.5 concludes and presents some policy implications.

3.2 Literature Review

As it was previously mentioned in the introductory part of this chapter, public capital stock is considered an essential determinant for a country's economic activity. Therefore, it is normal that research regarding the role of public investment on economic growth has been the centre of attention of many economic researchers.

One of the first studies produced in this line of research was that of Aschauer (1989a). The author tried to explain the decline in the United States (US) productivity in the 1970s and 1980s with the fall in the country's public infrastructure spending. Indeed, the results from his study confirmed this hypothesis: the decrease in public infrastructure spending affected US productivity in both decades negatively.

Years later, Aschauer (1998) once again analysed the relationship between public capital and economic growth. This time, the results pointed to that the relationship between these variables could be nonlinear. In other words, too little or too much public capital could produce negative externalities in the economy.

According to Aschauer (1998), the answer to the perfect amount of public capital should be in the middle of these two options—a vision that was similar to that of Barro (1990). According to his results, the estimated growth-maximising public capital stock was about 61% of the private capital stock.

Aschauer (1998) also found that the majority of the US states that he studied had a public capital ratio below the growth-maximising level. Thus, the increase in public capital stock would enhance growth in most of these states. Moreover, in his view, these states should also redirect their expenditures from non-investment consumption spending (e.g. defence spending) to public investment, as this would also contribute to growth.

There is no doubt that after the publication of Aschauer's (1989a) study, there was increased interest in this theme. In the review by Sturm et al. (1998), the results from the first group of studies that followed the one from Aschauer's (1989a) can be appreciated. In general, their conclusions support the vision that public capital positively affects a country's output.

However, the large elasticities reported in this first group of studies led to the emergence of a set of critics who pointed out some econometric and methodological issues (e.g.

Gramlich, 1994). Some of the problems raised were the authors' contempt for the possibility of reverse causation (i.e. they did not address the issue of endogeneity) and for the possible presence of spurious correlation linked with the non-stationarity of the data.

The first studies applied time-series methods to investigate the relationship between public capital and growth (e.g. Munnell, 1990; Aschauer, 1989a), being followed by authors who preferred the use of cross-sectional data methods (e.g. Nourzad and Vrieze, 1995). As the econometric techniques evolved and new databases appeared, the authors started to considered panel data procedures as the preferable option (e.g. Charlot and Schmitt, 1999).

Looking at Romp and De Haan's (2007) critical survey, most of the authors used the production function approach — usually based on the Cobb–Douglas production function — to study the effects of public capital on economic growth. In fact, this approach was still applied in some recent studies (e.g. Calderón et al., 2015).

However, given some problems related to the production function approach — e.g. it does not address the possibility of reverse causation and violates the marginal productivity theory — some authors decided to follow other methodologies. Some examples are panel models, simultaneous equation models, use of instrumental variables and the use of the cost/profit function approach (e.g. Cohen and Paul, 2004; Shioji, 2001).

One approach that has gained considerable attention is the use of vector autoregression (VAR) and vector error correction (VECM) models (e.g. De Jong et al., 2018, Dreger and Reimers, 2014; Kamps, 2005). Following De Jong et al. (2018), some advantages of this approach are that it does not impose causal relationships, it allows testing for the existence of causal relationships in any direction, and it allows indirect links between the variables.

A major difficulty that researchers have faced in the study of this issue is the uncertainty regarding the best variable to act as a proxy for public capital. Nowadays, this problem has been attenuated thanks to the release of the "*Investment and Capital Stock Dataset*" by the IMF (2017).

The "*Investment and Capital Stock Dataset*" (IMF, 2017) is composed of data on public, private and public-private partnership (PPP) capital stocks between 1960 and 2017[1] for 170 countries. This database has made it possible to extend analyses to a higher number of years and countries, with its measures of capital stocks being comparable across countries. The public and private capital stocks were constructed based on the methodology employed by Kamps (2006) and Gupta et al. (2014), according to the perpetual inventory method (PIM).

Although it is considered that the "*majority of current infrastructure investment is public*" (Cavallo and Powell, 2019; p. 68), the fact that private capital stock is also present in the previously mentioned database is extremely important. Indeed, most of the authors who studied the effects of public capital on growth usually also include private capital in their estimations.

The inclusion of such a variable is extremely important, not only to compare the effects of both public and private capital on economic growth but also to explore the effects of public capital on private capital (crowding-in/crowding-out effects). As it was already stressed in previous literature, the effect of public capital on private capital can be a channel for enhancing or diminishing a country's economic output (e.g. Nguyen and Trinh, 2018; Dreger and Reimers, 2014; Coenen et al., 2013).

Regarding LAC, as it was already stressed, the previously mentioned study by Ramirez and Nazmi (2003) is the most cited study on this theme for this region. The sample of this study was composed of nine LA nations, with a time horizon ranging from 1983 to 1993. The results pointed out that both public and private investment spending contributed to increasing these countries' economic growth. The authors concluded that indiscriminate private and public investment cuts could be harmful to their long-term economic growth.

Despite the Ramirez and Nazmi (2003) results and despite the undeniable importance of this study, there is a need to expand the study on the impacts of capital stock on this region's growth. Especially because new databases, new econometric techniques, and new ideas have arisen since its publication.

Again, looking, for example, to the extensive literature surveys of Pereira and Andraz (2013), Straub (2008) and Romp and De Haan (2007), or to the recent meta-analytic

[1] At the time of the publicaton of Santiago et al. (2019) the "*Investment and Capital Stock Dataset*" only covered data until 2015.

studies of Núñez-Serrano and Velázquez (2017) and Bom and Ligthart (2014), the general conclusion seems to be that public capital has a positive and statistically significant effect on economic growth. These authors also point to the fact that this positive effect is usually stronger in the long-run.

However, despite this somewhat consensual view, there is still a vast level of heterogeneity in the studies' estimates. As in other research fields, the diversity of results is mainly linked with the time horizon, the sample, the aggregation level, the measure of public capital and the estimation method that the authors chose to use (De Jong et al., 2018).

After this review, it is noticed that the research on the macroeconomic effects of public capital stock is, undoubtedly, a subject that continues to arouse the interest of various authors. Probably, this is due to the fact that although the view that "*public investment is a key input in the creation of a network of physical assets over time, including economic infrastructure (roads, airports, electric utilities, etc.) and social infrastructure (public schools, hospitals, prisons, etc.)*" (IMF, 2017; p. 1), its effects on growth seem to be still not entirely consensual, as this effect depends on several factors.

Due to the lack of studies centred on the LAC and to the pressure that the region's governments are facing concerning the need to increase their public investment levels (especially in infrastructure development), there is a need to expand the study of this relationship in this region. Indeed, as the regional growth strategies will probably rely on these countries' public investment plans, it is essential to produce studies in order to help the region's policymakers on the development of such strategies.

3.3 Data and Methodology

To achieve the goals of this chapter, annual data from 1970 until 2014 was collected for a panel of 30 LAC countries. Namely for Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay and Venezuela.

It is important to refer that both time horizon and countries were chosen following the available data. Before proceeding, it should also be mentioned that the econometric analysis was conducted through the use of the Stata 15 and E-Views 10 statistical

software. The name, definition and sources of the variables that were chosen to perform the analysis are shown in Table 3.1.

Table 3.1 – Variables description

Variable	Definition	Source
Y	Gross domestic product (current prices), in billions of national currency	Investment and Capital Stock Dataset
P	Total population, in the total number of persons	World Development Indicators
KPUB	General government capital stock (current cost), in billions of national currency	Investment and Capital Stock Dataset
KPRIV	Private capital stock (current cost), in billions of national currency	Investment and Capital Stock Dataset

The gross domestic product (current prices) in billions of national currency (Y) will be the proxy for economic growth. The variables general government capital stock (current cost) in billions of national currency (KPUB) and private capital stock (current cost) in billions of national currency (KPRIV) will be the proxies for public capital stock and private capital stock, respectively.

All the previously mentioned variables were retrieved from the "*Investment and Capital Stock Dataset*" released by the IMF (2017). In addition, the variable total population in the total number of persons (P), retrieved from the "*World Development Indicators*" of the World Bank, was used to convert them into their per capita values (YPC, KPUBPC, KPRIVPC).

To investigate the short-run effects and Granger-causal relationships between the variables it will be used the panel vector autoregression (PVAR) developed by Holtz-Eakin et al. (1988), using the estimator proposed by Love and Zicchino (2006). Then, in order to access the long-run impacts of the public capital stock and private capital stock on economic growth, it will be used the panel dynamic ordinary least squares (PDOLS) and the panel fully modified ordinary least squares (PFMOLS) estimators developed by Pedroni (2001a, 2001b).

The PVAR model is used in various research fields, but it is most commonly used by macroeconomists working with data for a vast number of countries and with a long-time span (Kroop and Korobilis, 2016). Additionally, PVARs are an excellent way to model how shocks are transmitted across countries (Canova and Ciccarelli, 2009) and have the advantage of treating all variables as endogenous (Abrigo and Love, 2016). However, the

existence of restrictions based on statistical procedures may be imposed on disentangling the impact of exogenous shocks on the system.

Why was this methodology used in this investigation? Because in panels with long periods (macro-panels), as in the case of this analysis, the presence of cointegration between the variables and the endogeneity is expected. Indeed, to handle the problem of endogeneity and cointegration, the literature recommends using PVAR models. Moreover, the use of this methodology in order to handle these phenomena is confirmed in their advantages, such as:

- it is helpful in the presence of little theoretical information about the relationship between the variables to guide the specification of the model;
- it was created to address the endogeneity and cointegration problem among the variables of the model;
- it can account for any delayed effects of the variables under consideration, and thus determine whether the effects of the variables are in the short- or long-run or both;
- it allows country fixed-effects to be included that capture the time-invariant components that may affect economic growth and global time effects that affect all countries in the same period of time;
- it can account for any global shocks that impact all countries at the same time in the model.

The estimator proposed by Love and Zicchino (2006) allows the presence of stationary endogenous variables and unobserved individual heterogeneity. The specification of the PVAR model is described in Equation (3.1):

$$Z_{it}=T_0+T_1Z_{it-1}+f_i+d_{c,t}+\varepsilon_t, \quad (3.1)$$

where Z_{it} represents the vector of the variables in the analysis, T_0 denotes the vector of constants, T_1Z_{it-1} denotes the polynomial matrix, f_i denotes the fixed effects, $d_{c,t}$ denotes the time fixed effects and ε_t is the random errors term.

The variables used to estimate this model were: DLYPC, DLKPUBPC, and DLKPRIVPC. The use of the variables in the first differences of natural logarithms is due to the PVAR model requiring that all variables be I(0), i.e. stationary. The stationarity of variables can

be confirmed by the cross-sectionally augmented Im, Pesaran and Shin (CIPS) test (Pesaran, 2007) that will be evidenced in Table 3.4. The conceptual framework (Figure 3.1) highlights the methodological approach that will be used in the PVAR model.

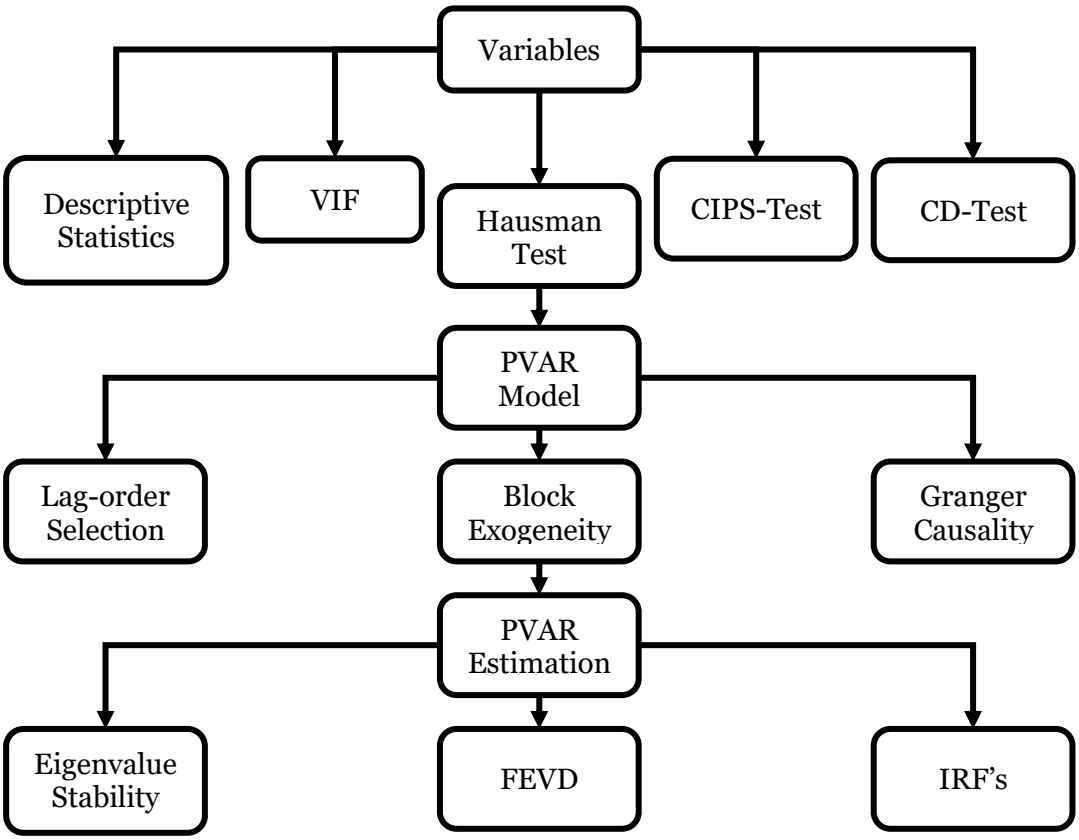


Figure 3.1 – Conceptual framework (PVAR)

Due to the use of the variables in the first differences of natural logarithms in the PVAR estimation, the capacity to analyse the long-run relationships is lost. Thus, to explore the long-run relationship between economic growth, public capital stock, and private capital stock and obtain the long-run parameters, the PDOLS and PFMOLS estimators will be used.

In order to estimate the PDOLS and PFMOLS, it is essential to test for the presence of cointegration between the variables and granting that all variables are integrated of order one. In the presence of cointegration, the PDOLS and PFMOLS estimators provide better results than the ordinary least squares (OLS) estimator, given that they correct some of the biases produced by the OLS estimator (e.g. Salahuddin et al., 2015). Hence, the long-run relationship between economic growth, public capital stock and private capital stock will be given by the Equation (3.2):

$$LYPC_{it}=\alpha_i+\beta_i LKPUPPC_{it}+\gamma_i LKPRIVPC_{it}+\varepsilon_{it} \quad (3.2)$$

where the α_i represents the intercept, β_i and γ_i represent the elasticities of public capital stock and private capital stock, respectively, and ε_{it} represents the error term. The prefix "L" denotes natural logarithms.

Before proceeding with the estimations of the PVAR, PDOLS, and PFMOLS, there is the need to compute a battery of preliminary and specification tests. This should be done in order to confirm the requirements of the models and, thus, be able to guarantee the trustworthiness of the achieved outcomes. Therefore, one can start by introducing the descriptive statistics of the per capita variables and the results of the cross-section dependence (CD) test (Pesaran, 2004) in Table 3.2. The prefixes "L" and "D" denote natural logarithms and first differences of the variables, respectively.

Table 3.2 – Descriptive statistics and CD-test

Variables	Descriptive statistics					Cross-sectional dependence (CD) test		
	Obs.	Mean	Std. Dev.	Min.	Max.	CD-test	Corr.	Abs. (corr.)
LYPC	1350	-11.40378	4.7331	-31.14783	9.127953	81.73***	0.584	0.844
LKPUBPC	1350	-11.65031	4.804759	-30.13868	8.777058	75.96***	0.543	0.825
LKPRIVPC	1350	-11.01015	4.603375	-28.63935	9.17065	81.46***	0.582	0.834
DLYPC	1320	0.0733062	1.918062	-31.24936	28.30312	22.94***	0.166	0.240
DLKPUBPC	1320	0.0499681	2.088308	-31.71728	28.01527	10.72***	0.078	0.161
DLKPRIVPC	1320	0.0696745	1.516823	-27.12892	4.560019	11.96***	0.086	0.167

Notes: Obs., Observations; Std. Dev., Standard Deviation; Min., Minimum, Max, Maximum; Corr., Correlation; Abs. (corr.), Absolute Correlation; the CD-test has N (0,1) distribution under the H0: cross-section independence; ***, ** denote statistical significance at 1% and 5% level, respectively; the Stata commands *sum* and *xtcd* were used to compute the descriptive statistics and the CD-test, respectively.

Given the results from the CD-test (Table 3.2), it can be concluded that cross-sectional dependence is present in all variables, both in natural logarithms and in first differences. This means that a correlation exists between the series across countries. One reason for this fact can be linked with the common shocks that the crosses share.

The next step of this analysis was examining the correlation matrix and the variance inflation factor (VIF) statistics (Belsley et al., 1980). This allows checking if collinearity and multicollinearity could raise problems to the estimation. The results from both tests are shown in Table 3.3.

Table 3.3 – Correlation matrices and VIF statistics

	LYPC	LKPUBPC	LKPRIVPC		DLYPC	DLKPUBPC	DLKPRIVPC
LYPC	1.0000			DLYPC	1.0000		
LKPUBPC	0.9047	1.0000		DLKPUBPC	0.2611	1.0000	
LKPRIVPC	0.9294	0.8887	1.0000	DLKPRIVPC	-0.0446	0.3509	1.0000
VIF		4.76	4.76			1.14	1.14
Mean VIF		4.76				1.14	

Notes: In the case of the VIF test, the values are lower than the typically assumed benchmarks: 10 in the case of the VIF values, and 6 in the case of the mean VIF values; the Stata commands *corr* and *estat vif* were used to compute the correlation matrix and VIF statistics, respectively.

Although the results have pointed to a relatively high degree of collinearity between LYPC, LKPUBPC, and LKPRIVPC (an expected outcome given their closed relationship) when in first differences, the variables show a low degree of collinearity. As the VIF and mean VIF values were both low for the variables in natural logarithms and first differences, it can be considered that multicollinearity does not raise concerns for the analysis. Therefore, the estimation can proceed without further worries.

As the presence of cross-sectional dependence was detected for all the variables in natural logarithms and first differences, the first-generation unit root tests ceased to be efficient to investigate the stationarity of the variables (Neves et al., 2018). To overcome this issue, it was applied the second-generation unit root test of Pesaran (2007), also known as panel unit root test or cross-sectionally augmented Im, Pesaran and Shin (CIPS) test. The results of this test are presented in Table 3.4.

Table 3.4 – CIPS test

Variables	CIPS (Zt-bar)		
	Lags	Without trend	With trend
LYPC	0	-0.320	5.682
	1	0.027	1.161
	2	0.624	1.325
	3	0.834	1.685
LKPUBPC	0	2.693	2.126
	1	0.521	-1.718**
	2	1.675	0.292
	3	3.400	1.621
LKPRIVPC	0	4.144	5.156
	1	1.921	2.015
	2	1.619	2.441
	3	3.760	3.566
DLYPC	0	-11.321***	-13.447***
	1	-6.819***	-8.214***
	2	-4.935***	-6.008***
	3	-3.402***	-3.504***
DLKPUBPC	0	-16.663***	-17.456***
	1	-11.093***	-11.246***
	2	-7.525***	-6.489***
	3	-5.556***	-4.139***
DLKPRIVPC	0	-16.255***	-16.612***
	1	-10.576***	-11.548***
	2	-6.725***	-6.800***
	3	-4.338***	-3.672***

Notes: ***, **, denote statistical significance at 1% and 5% level, respectively; CIPS assumes that cross-sectional dependence is in the form of a single unobserved common factor and H0: series is I(1); the Stata command *multipurt* was used to compute this test.

Looking at the results from the previous table (Table 3.4), one can see that all variables in logarithms are integrated of order one, except for the natural logarithm of public capital stock per capita (LKPUBPC) with the trend and one lag. In first differences, all variables are stationary, with and without trend, which is a necessary condition for the PVAR estimation.

The following estimation step was computing the Hausman test (Hausman, 1978). This test allows checking if fixed or random effects are present in the panel. In the framework of this analysis, the Hausman test was applied to three PVAR model specifications, each one with a different dependent variable (DLYPC, DLKPUBPC, DLKPRIVPC). The results from these tests can be seen in Table 3.5.

Table 3.5 – Hausman tests

	Model with DLYPC as dependent variable	Model with DLKPUBPC as dependent variable	Model with DLKPRIVPC as dependent variable
Hausman test	FE vs. RE	FE vs. RE	FE vs. RE
	Chi2(2) = 6.39 (0.0409)	Chi2(2) = 0.05 (0.9737)	Chi2(2) = 9.00 (0.0111)

Notes: H0: difference in coefficients not systematic (random-effects); The values in () represent the Prob>chi2, if < 5%, it means that we can reject the H0; the Stata command *hausman* was used to compute these tests.

Looking at the results (Table 3.5), it can be seen that the presence of fixed effects was detected in the specifications with DLYPC and DLKPRIVPC as the dependent variables. Due to the confirmation of the presence of fixed effects, correlation problems between the regressors can arise.

In order to surpass the previously mentioned problem, the PVAR estimation will be conducted using the "*Hermelet procedure*" (Arellano and Bover, 1995), which allows removing the fixed effects. The system is then estimated using the generalised method of moments (GMM), using the lags of the regressors as instruments. Regarding the PVAR estimation, the last preliminary test is related to the optimal lag-order selection. The results of the lag-order selection criteria test can be seen in Table 3.6.

Table 3.6 – Lag order selection criteria

Lag	CD	J	J-p value	MBIC	MAIC	MQIC
1	0.4063907	28.44341	0.3883925*	-162.3051	-25.55659	-77.13302
2	0.6168017	25.56291	0.1101798	-101.6027	-10.43709	-44.82137
3	0.7423995	8.059086	0.5282029	-55.52375	-9.940914	-27.13305

Notes: This procedure displays the coefficient of determination (CD), Hansen´s J statistic (J), and its p-value (J p-value) (Hansen, 1982), and the Bayesian information criterion (MBIC), the Akaike information criterion (MAIC), and the Quinn information criterion (MQIC) introduced by Andrews and Lu (2001); the test was conducted for first- to third-order panel VAR using the first four lags of the regressors as instruments; The Stata command *pvarsoc* was used to compute the lag-order selection criteria test.

After passing Hansen's J test (Hansen, 1982), which is a statistical test used for testing over-identifying restrictions—following the J-p value, which is higher than 10%, it is clear that the null hypothesis cannot be rejected: the overidentification restrictions are valid—the optimal lag length should be the one that minimises the MBIC, MAIC and MQIC information criteria (Andrews and Lu, 2001). Looking at Table 3.6, the MBIC, the MAIC and the MQIC criteria are lower with one lag. According to these results, a first-order PVAR should be estimated.

As it was previously mentioned, in order to access the long-run elasticities of the public capital stock and private capital stock through the PDOLS and PFMOLS, there is the need to ensure that there is a cointegrating relationship between the variables. The other

condition is that the variables should be I(1), a condition that was already confirmed in the CIPS test.

As cross-sectional dependence was detected in all variables, it becomes suitable to use the cointegration test of Westerlund (2007) to verify if there is a cointegrating relationship between the variables since this test is robust to cross-sectional dependence (e.g. Fuinhas et al., 2015). The results of the Westerlund (2007) test are displayed in Table 3.7.

Table 3.7 – Westerlund cointegration test

Statistics	Value	Z value	p-value	Robust p-value
Gt	-1.974	-3.096	0.001	0.004
Ga	-14.027	-8.217	0.000	0.000
Pt	-17.313	-9.167	0.000	0.013
Pa	-41.335	-43.400	0.000	0.000

Notes: Bootstrapping regression with 800 reps. H0: No cointegration; H_1 Gt and Ga test the cointegration for each country individually, and Pt and Pa test the cointegration of the panel as a whole; the Stata command *xtwest* was used.

Following Berhane (2018, p. 169): "*Gt and Pt are computed with the conventional standard error of the parameters of the error correction model, whereas Ga and Pa are adjusted for heteroscedasticity and autocorrelations based on two standard errors developed by Newey and West (1994)*". As it can be seen in Table 3.7, for Gt, Ga, Pt and Pa, the p-values reject the null hypothesis of no cointegration at the 1% statistical significance level, meaning that a cointegrating relationship exists between the variables, both for each country and the panel as a whole.

Through the analysis of the robust p-values, which account for cross-sectional dependence, one can see that the null hypothesis (i.e. no cointegration) is still rejected at the 1% significance level for Gt, Ga and Pa, and at the 5% significance level for the case of Pt. Overall, these results provide strong evidence of the existence of a cointegrating relationship between LYPC, LKPUBPC and LKPRIVPC in the LAC countries.

After carrying out all these preliminary and specification tests, the PVAR model can be now estimated, as also the PDOLS and PFMOLS models. Consequently, the results from the estimations, as well as their respective discussion, will be presented in the next section of this chapter (Section 3.4).

3.4 Results and Discussion

The PVAR model was estimated using one lag, the "*gmmstyle*" option (Holtz-Eakin et al., 1988), and with the first four lags of the regressors as instruments. The "*gmmstyle*"

option replaces the missing values with zeroes being capable of producing more efficient estimates. The first order PVAR results are listed in Table 3.8.

Table 3.8 – PVAR model results

Variable	$DLYPC^{(t)}$	$DLKPUBPC^{(t)}$	$DLKPRIVPC^{(t)}$
$DLYPC_{(t-1)}$	-0.0252587	0.4696266***	0.3100442***
$DLKPUBPC_{(t-1)}$	-0.1166286***	-0.2240945***	-0.1387485***
$DLKPRIVPC_{(t-1)}$	0.4073608***	0.0871552	0.089169**

Notes: ***, and ** denote statistical significance at 1%, and 5%, respectively. The Stata command *pvar* with one lag was used with *gmmstyle* option; Instruments: l (1/4).

The results of the PVAR model seem to point to the existence of endogeneity in the variables. Indeed, the lagged variables in all PVAR equations are at least statistically significant at the 1% and 5% levels.

Moreover, the results from the PVAR model also seem to indicate that gross domestic product per capita (DLYPC) is, indeed, a driving force for the increase of the LAC capital stock. Looking at Table 3.8, it can be seen that a 1% increase in gross domestic product per capita (DLYPC) leads to an increase of 0.46962% in the public capital stock per capita (DLKPUBPC) and to an increase of 0.31004% in the private capital stock per capita (DLKPRIVPC).

Additionally, the outcomes of Table 3.8 also indicate that an increase in the private capital stock per capita (DLKPRIVPC) has a positive effect on the gross domestic product per capita (DLYPC) of these group of countries. A 1% increase in DLKPRIVPC leads to an increase of 0.40736% on DLYPC. Regarding the effect from the private capital stock per capita (DLKPRIVPC) on the public capital stock per capita (DLKPUBPC), although it appears to be positive - a 1% increase in DLKPRIVPC leads to an increase of 0.08715% in the DLKPUBPC - there is a lack of statistical significance, which means that it cannot be guaranteed that this effect actually occurs.

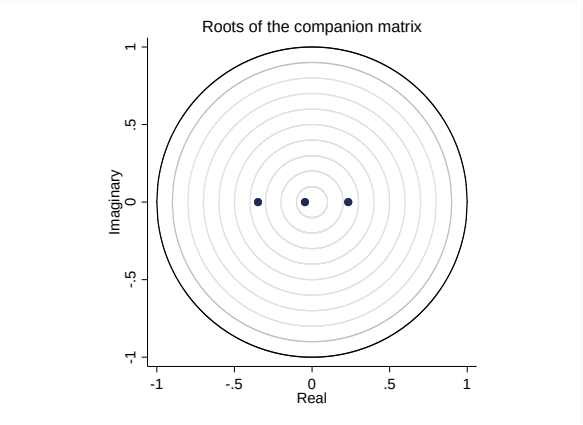
Conversely, looking at the effects from the public capital stock per capita (DLKPUBPC) on both the gross domestic product per capita (DLYPC) and private capital stock per capita (DLKPRIVPC), they appear to be negative. A 1% increase in DLKPUBPC seems to lead to a decrease of 0.11662% in the case of the DLYPC and of 0.13874% in the case of the DLKPRIVPC.

After the PVAR estimation, it is important to check its stability by computing the eigenvalue condition. According to this test, if all the eigenvalues are within the unit

circle, the stability condition is confirmed, and, therefore, the PVAR model is stable. The graph of the eigenvalues is displayed in Table 3.9.

Table 3.9 – Eigenvalue stability condition

Eigenvalue			Graph
Real	Imaginary	Modulus	
-0.3480847	0	0.3480847	
0.2333451	0	0.2333451	
-0.0454445	0	0.0454445	



Notes: All the eigenvalues are inside the unit circle, meaning PVAR satisfies the stability condition. The Stata command *pvarstable* was used to compute this test after the PVAR estimation.

Through the graph in Table 3.9, it can be seen that the stability condition is fulfilled. All the eigenvalues are within the unit circle. In addition to confirming the stability of the PVAR model, this result also seems to reinforce the conclusion that the variables are all stationary (see, e.g. Lütkepohl, 2005).

After confirming the PVAR model stability, one can now compute the Granger causality test (Abrigo and Love, 2016) in order to explore the causal relationships that may exist between the variables. The null hypothesis of the Granger causality test is the absence of causality. If the null is rejected, it means that there is a causal relationship between the variables. The results of the Granger causality test are exhibited in Table 3.10.

Table 3.10 – Granger causality test

Variables	DLYPC	DLKPUBPC	DLKPRIVPC
DLYPC does not cause	-	124.094***	113.287***
DLKPUBPC does not cause	15.803***	-	15.633***
DLKPRIVPC does not cause	88.626***	2.375	-
ALL	89.039***	200.053***	124.625***

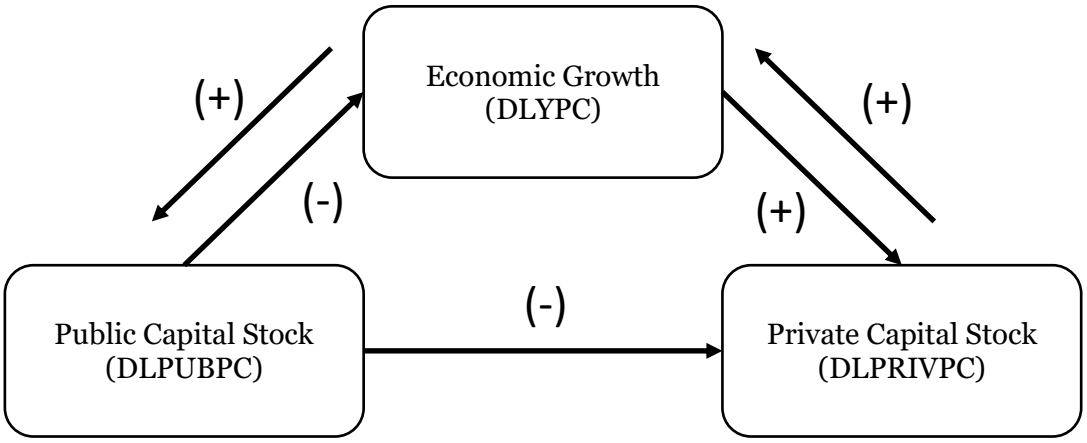
Notes: *** denotes the statistical significance of 1%; the Stata command *pvargranger* was used to compute the Granger causality test after the PVAR estimation.

Looking at the results from Table 3.10, there is evidence of:

- a bidirectional causality between DLYPC and DLKPUBPC;
- a bidirectional causality between DLYPC and DLKPRIVPC;

- a unidirectional causality running from DLKPUBPC to DLKPRIVPC.

The signal and the direction of the causal relationships are now displayed in Figure 3.2 to allow a more concise interpretation of the outcomes that were found. It is also important to stress that all these causalities were found at the 1% level of statistical significance and that by the analysis of the exogeneity blocks (ALL) in Table 3.10, the presence of endogeneity is confirmed. This fact reinforces the use of the PVAR model, given that it is able to deal with this feature (Love and Zicchino, 2006).



Notes: The causality signals were based on the coefficients of the PVAR estimation (Table 3.8); the arrows denote 1% statistical significance level.

Figure 3.2 – Summary of the causalities according to the Granger causality test

Through the analysis of Figure 3.2, it can be seen that:

- the bidirectional causality between gross domestic product per capita (DLYPC) and public capital stock per capita (DLKPUBPC) has a positive signal when the causality runs from DLYPC to DLKPUBPC and a negative signal when it runs from DLKPUBPC to DLYPC;

- the bidirectional causality between gross domestic product per capita (DLYPC) and private capital stock per capita (DLKPRIVPC) has a positive signal in both directions;

- the unidirectional causality running from public capital stock per capita (DLKPUBPC) to private capital stock per capita (DLKPRIVPC) has a negative signal.

Overall, the results seem to indicate that economic growth, here proxied by DLYPC, can contribute to the increase in both the public and private capital stocks, DLKPUBPC and

DLKPRIVPC, respectively. They also seem to show that private capital stock (DLKPRIVPC) is the only one of the two types of capital stock which appears to positively contribute to the LAC countries economic growth (DLYPC) in the short-run.

In fact, from the outcomes of Figure 3.2, it is observed that public capital stock (DLKPUBPC) presents a detrimental effect on these countries growth (DLYPC) in the short-run. In addition to this adverse effect, the public capital stock (DLKPUBPC) also seems to be detrimental for the LAC private capital stock (DLKPRIVPC). This outcome opens the possibility for the existence of a crowding-out effect in this region, i.e. public capital seems to crowd-out private capital in the LAC.

Relatively to the positive causalities that run from gross domestic product per capita (DLYPC) to public capital stock per capita (DLKPUBPC) and private capital stock per capita (DLKPRIVPC), it is far from unexpected. For example, Blomstrom et al. (1996) had already reached similar inferences with fixed capital formation, concluding, in their study, that increases in economic growth usually lead to rises in the rates of capital formation. In accordance, it is expected that a boost on a country's economic output leads to an increase in the economy's investment degree – i.e. to an increase in both the public and private capital stocks.

Similarly, it would be expected that both public and private capital stocks also revealed a positive effect on economic growth, as the neo-classic growth models postulate (e.g. Solow, 1956). However, by the outcomes from the PVAR and the Granger Causality test, it is seen that only the causality runs from private capital stock per capita (DLKPRIVPC) to gross domestic product per capita (DLYPC) shows a positive signal.

Following Agénor and Moreno-Dodson (2006), an increase in the public capital stock may have detrimental effects on economic growth in the short-run if it produces a crowding-out effect on private investment. This effect was clearly identified in the estimation, with the public capital stock per capita (DLKPUBPC) showing to have a negative unidirectional causal relation with the private capital stock per capita (DLKPRIVPC). This adverse effect underlines the possibility that public and private capital act as substitutes in LAC, competing with each other instead of acting as complements (Erden and Holcombe, 2006).

Still on the identified crowding-out effect, looking at the works of Castellani et al. (2019) and Aschauer (1989b), one would expect the presence of the opposite effect (crowd-in). This is because the first work indicates a significant public investment gap in this region,

and the second shows that an increase in public capital stock should raise the returns to private capital.

In accordance with the previous ideas, it would be expected that public capital contributed to increasing countries' output growth, especially in the cases where the existing levels of public capital stock are relatively low (Romp and De Haan, 2007). This should be the case of the LAC region, where there is a lower public investment stock, especially when compared with regions that are at a similar development stage, e.g. the East Asia and Pacific (EAP) region (Castellani et al. 2019).

However, looking, for example, at the works of Bahal et al. (2018), Presbitero (2016) and Cavallo and Daude (2011), there are some critical factors that could easily affect the relationship between public and private investment and, subsequently, lead to a negative effect from public capital on growth. In sum, these authors state that countries with weak institutions, with greater difficulty in access to financing and with worse absorptive capacity are more prone to reveal a crowding-out effect from public investment on private investment. All these characteristics seem to be present in most of the countries from the LAC region, which means that they could possibly explain the achieved result.

Moreover, the adverse effect that public capital stock per capita (DLKPUBPC) appears to have on gross domestic product per capita (DLYPC) can also be the result of the regional infrastructure shortfalls (Faruqee, 2016) or due to this region's inaccurate public investment strategies (Gupta et al. 2014). Additionally, it should not be forgotten that, in the LAC region, this issue could be exacerbated by a group of factors that are usually linked to this group of countries as, for example, corruption, political instability, and the existence of "white elephants (Pritchett, 2000).

Lastly, it should not be forgotten that public capital stock is not always centred on profit in contrast to private capital stock. In many situations, public investment projects are primarily aimed at increasing social welfare, often acting in areas where there is no private interest, i.e. areas where it is difficult to make a profit. This fact can lead to situations where the positive economic effects are not immediate (i.e., may not be immediately felt in the short-run).

In addition to the Granger causality test, it was also computed the forecast error variance decomposition (FEVD) and the impulse response functions (IRF's). The FEVD allows understanding the percentage that a variable explains of the forecast error variance of another variable that has been faced with a shock/innovation. In other words, the lapse

of time that a variable need to achieve equilibrium and the contribution of each variable to that purpose. The IRF's enable analysing the behaviour of one variable (i.e. the response variable) faced with a shock/innovation in another specific variable (i.e. the impulse variable) and the lapse of time that the response variable needs to return to equilibrium (Neves et al., 2018).

Furthermore, it should be stressed that the outcome of the eigenvalue stability condition (Table 3.9) conveys the idea that the FEVD and the IRF's have a known interpretation (Abrigo and Love, 2016). The results from the FEVD and the IRF's are given in Table 3.11 and Fig. 3.3, respectively.

Table 3.11 – Forecast error variance decomposition (FEVD)

Response variables	Forecast horizon	Impulse variables		
		DLYPC	DLKPUBPC	DLKPRIVPC
DLYPC	1	1	0	0
	2	0.9201382	0.0035039	0.0763579
	5	0.9194797	0.004039	0.0764813
	10	0.9194771	0.004039	0.0764838
DLKPUBPC	1	0.1113593	0.8886407	0
	2	0.2162131	0.7807284	0.0030585
	5	0.2208831	0.7631297	0.0159872
	10	0.220901	0.7631051	0.0159939
DLKPRIVPC	1	0.0007584	0.0299305	0.9693111
	2	0.1129587	0.0505504	0.8364909
	5	0.1169415	0.0497397	0.8333188
	10	0.116957	0.0497396	0.8333033

Notes: FEVD followed the Cholesky decomposition and was performed using 1000 Monte Carlo simulations for 10 periods; The Stata command *pvarfevd* was used to perform the FEVD.

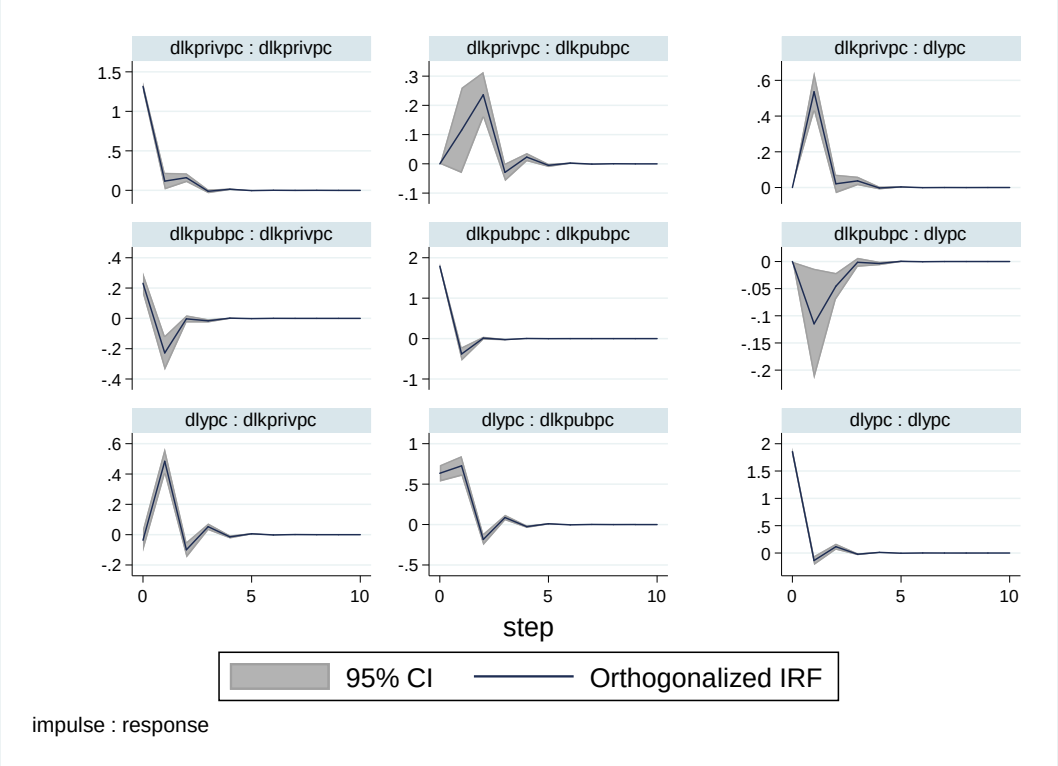
Looking at Table 3.11, it can be seen that, in the first period, DLYPC, DLKPUBPC, and DLKPRIVPC, are all self-explanatory regarding their forecast error variances. The forecast error variance of these variables is mainly explained by shocks to themselves (100%; 88.86%; and 96.93%, respectively).

Still, in the first period, it is seen that 11.14% of the DLKPUBPC forecast error variance is explained by DLYPC and that 2.99% of the DLKPRIVPC forecast error variance is explained by DLKPUBPC. Additionally, DLKPRIVPC explains 0% of the DLKPUBPC forecast error variance in this same period, and DLYPC explains only a derisory part of the DLKPRIVPC forecast error variance (however, in the second period, that percentage significantly increases to 11.30%).

As one moves forward in time, the percentage of the forecast error variance, which is explained by shocks to themselves, decreases, while the percentage of the forecast error variance, which is explained by shocks in the other variables, increases.

Advancing to the tenth period, 91.95% of the forecast error variance of DLYPC is explained by itself, 0.4% by DLKPUBPC, and 7.65% by DLKPRIVPC. Regarding DLKPUBPC, 76.31% of its forecast error variance is explained by itself, 22.09% by DLYPC, and 1.6% by DLKPRIVPC. Lastly, concerning the DLKPRIVPC, it is seen that 83.33% of its forecast error variance is explained by itself, 11.70% by DLYPC, and 4.97% by the DLKPUBPC.

Overall, the FEVD results seem to acknowledge the idea that private capital stock (DLKPRIVPC) exerted a more significant influence on the LAC countries' economic growth (DLYPC) when compared with the public capital stock (DLKPUBPC) and that economic growth (DLYPC) has a considerable influence on the variance of both public (DLKPUBPC) and private capital stocks (DLKPRIVPC). Regarding the two types of capital, the results show that the private capital stock (DLKPRIVPC) forecast error variance is more influenced by shocks in the public capital stock (DLKPUBPC) than the public capital stock (DLKPUBPC) forecast error variance is influenced by shocks in the private capital stock (DLKPRIVPC).



Notes: The Stata command *pvarirf* was used to estimate the IRF's.

Figure 3.3 – Impulse response functions (IRF's)

Turning to the IRF's results (Figure 3.3), it is seen that after a shock, all variables seem to converge to equilibrium. Once again, this fact supports the stationarity of DLYPC,

DLKPUBPC and DLKPRIVPC. Regarding the response of the variables to the respective impulses, it can be observed that:

- concerning an impulse on the DLYPC, both DLKPRIVPC and DLKPUBPC respond positively;
- concerning an impulse on the DLKPUBPC, both DLYPC and DLKPRIVPC respond negatively;
- concerning an impulse on the DLKPRIVPC, both DLYPC and DLKPUBPC respond positively.

In sum, the results and conclusions from the FEVD and the IRF's highlight the effects which were found in the PVAR model and on the subsequent Granger causality test: economic growth (DLYPC) has positive effects on both private capital stock (DLKPRIVPC) and public capital stock (DLKPUBPC); private capital stock (DLKPRIVPC) has a positive effect on economic growth (DLYPC); and public capital stock (DLKPUBPC) has adverse effects on both economic growth (DLYPC) and private capital stock (DLKPRIVPC).

However, as it was previously stressed, the effects which were uncovered through the PVAR analysis were short-run effects. Thus, the PDOLS and PFMOLS estimators were used in order to assess the effects of the public capital stock and private capital stock on the long-run economic growth of these LAC countries. The use of two different estimators allows seeing whether the estimated parameters are oversensitive to the estimation technique. The estimation results are presented in Table 3.12.

Table 3.12 – PDOLS and PFMOLS results

Dependent variable: LYPC		
Independent variables	PDOLS	PFMOLS
LKPUBPC	0.405942***	0.413921***
LKPRIVPC	0.610754***	0.600292***

Notes: *** denote statistical significance of 1%; the PDOLS and PFMOLS were computed in the E-Views 10 statistical software.

The results of Table 3.12 are unanimous: both public capital stock per capita (LKPUBPC) and private capital stock per capita (LKPRIVPC) have a positive impact on the gross domestic product per capita (LYPC). Furthermore, the coefficients that were achieved by the PDOLS and PFMOLS estimators, and which can be considered as the long-run elasticities (Farhani, 2013), are relatively similar.

Both estimation techniques point to an enhancing effect from both public and private capital stocks on the long-run economic growth of these LAC countries. However, there seems to be a somewhat more significant impact of private capital stock per capita (LKPRIVPC) on gross domestic product per capita (LYPC).

One of the justifications for the positive impact of public capital stock (LKPUBPC) on economic growth (LYPC) in the long-run is that, as was stressed by Agénor and Moreno-Dodson (2006), the crowding-out effects of public capital stock are mainly observed in the short-run. In the long-run, these effects tend to dissipate, and the public capital stock starts to be able to foster economic growth. Erenburg and Wohar (1995) also found a similar result regarding the difference between the short-run and long/medium-run effects of public investment on economic growth. This situation seems to indicate that, in the LAC region, the public capital stock probably starts to crowd-in private capital in the long-run.

Moreover, another solid explanation for this turn can be associated with the fact that the impact of public capital on long-run economic growth is strongly related to public capital stock levels (Fournier, 2016) and efficiency (Berg et al., 2019). In a situation where there is a relatively low level of public capital and/or where past investments were inefficient — which seems to be the case of the sample of this analysis (Faruqee, 2016) — rises in public investment levels and efficiency are likely to lead to large marginal returns, hence, increasing output growth.

Regarding the impact of private capital stock (LKPRIVPC) on long-run economic growth (LYPC), the result is in line with the idea that higher investment rates lead to higher output levels (e.g. Solow 1956). Moreover, the fact that private capital has a higher coefficient than public capital seems to be a result that was already met by a vast range of past studies (e.g. Arslanalp et al., 2010).

Following Devadas and Pennings (2018), who investigated the effects of the increases in both public and private capital on economic growth, private investment is the most significantly responsible for the increase in the economic output of developing countries. As in the case of public capital stock, these positive effects are linked with the fact that these countries usually have low levels of private capital, which gives rise to relatively high returns to private investment.

Now that the proposed empirical analysis is complete and that their subsequent results were discussed, in the next section of this chapter (Section 3.5), it will be presented the

conclusions and the policy implications that can be drawn from them. It is expected that these policy implications help the regional policymakers on the development of growth-promoting policies for the LAC region.

3.5 Conclusion and Policy Implications

In this chapter, the PVAR, PDOLS, and PFMOLS methodologies were used to try to perceive the short- and long-run relationships between public capital stock, private capital stock, and economic growth in 30 LAC countries from 1970 to 2014.

Following the best econometric practices, the descriptive statistics, cross-sectional dependence test, correlation matrix, VIF statistics and CIPS second-generation unit roots test were computed. Their results allowed understanding the characteristics of the variables and countries under analysis and ensuring that the necessary conditions for the estimation were fulfilled.

The PVAR specification was based on the results of the lag-order selection criteria, and the stability of the PVAR model was confirmed through the observation of the eigenvalue stability condition. In order to explore the causal relationships between the variables, after the PVAR estimation, the Granger causality test was also computed, followed by the assessment of the FEVD and the IRF's.

In the second phase, the long-run impacts of the public and private capital stocks on economic growth were appraised using the PDOLS and PFMOLS estimators. Before estimating these models, the presence of a cointegrating relationship between the variables was confirmed through the Westerlund (2007) cointegration test.

Overall, the results point out that both public and private capital have a positive effect on the economic growth of these group of countries in the long-run. However, the results also show that, in the short-run, the public capital stock appears to hamper economic growth and that there seems to exist a crowding-out effect of public capital on private capital (which can be one of the possible reasons for the adverse effect of public capital stock on economic growth that was found).

Following the outcomes from the estimations, one can now turn to some policy implications that can be drawn from them and which, in the end, can help the LAC policymakers on the development of growth-promoting policies. The first one is that LAC governments should continue to promote public investment. At the same time, they should create or improve the conditions to encourage private investment.

Nevertheless, the increase in the LAC public and private capital should be done not only to enhance the regional growth but also to boost the competitiveness of the countries from the LAC region. In fact, following Faruqee (2016, p. 93): "*competitiveness is compromised in many LAC countries by the state of their infrastructure*".

Given the adverse effects that were found in the short-run from public capital on both private capital and economic growth, it is wise that the LAC governments pay a considerable amount of attention to how the public investment is materialised in this region. Especially due to the possibility of public capital stock displacing private capital stock.

One way to overcome the previous issue is to grant that public investment will be planned in a way so that the public and private capital act as complements and not as substitutes. This will allow not only boost economic growth and general social well-being as also increase the marginal productivity of the private capital.

The development of public-private partnership (PPP) structures can be one solution to increase the cooperation between the public and private sectors and increase private participation in areas of potential interest. In cases where governments face greater difficulty in, for example, financing public infrastructure projects, this could be a viable solution.

However, it is important that the PPP contracts be very well planned so that the investment can be sustainable and be able to meet the desired quality standards. It is also a priority to ensure that it does not originate harmful effects for the general public, as also for the taxpayers, with the creation of undesirable barriers to access these services or with the emergence of, for example, rent-seeking situations.

Moreover, in order to increase the efficiency of public investment projects and ensure that the money goes to projects of most significant interest, it is imperative to improve the selection, evaluation, and management of the public investment projects in the LAC region. As an example, governments could retrieve better outcomes through the investment in the maintenance/upgrade of the existing capital than through moving directly to the investment in new capital.

Finally, due to the macroeconomic stability problems which are usually associated with the countries from this region, it is important that the LAC governments weigh their fiscal space in order to ensure that no negative fiscal costs (e.g. distortionary taxes) will be associated with public investment, leading to situations where investment hampers

economic growth. A suggestion for the most challenging situations—e.g. countries with high public-debt-to-GDP (gross domestic product) ratios— could be the improvement of the public financing instruments or the search for new ways of funding (e.g. calling upon institutional investors and/or develop PPP schemes).

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Chapter 4

What effect does public and private capital have on income inequality? The case of the Latin America and Caribbean region

In this chapter, the effects that the Latin America and Caribbean (LAC) capital stock (public and private) had on the income inequality levels of 18 countries from this region were analysed, over a period ranging from 1995 to 2017, recurring to a panel autoregressive distributed lag (PARDL) model in the form of an unrestricted error correction model (UECM). The results from the three models that were estimated (with the total capital stock, the public capital stock, and the private capital stock) pointed for the existence of an enhancing effect from the capital stock on the income inequality of these countries in the short-run, suggesting that the investments were made in the already richer/wealthiest areas. In the long-run, the effects of capital stock on income inequality seem to vanish, probably due to the efforts to correct the previous detrimental effect. However, the lack of a statistically significant effect shows that physical capital still does not contribute to income inequality reduction. This means that, in the future, these countries should increase their physical capital investment levels at the same time as they improve/change the management and the selection criteria of these investments in order to be able to reduce their income gap.

4.1 Introduction

Despite the positive trend on the Latin America and the Caribbean (LAC) region's gross domestic product (GDP) growth – following the Organisation for Economic Co-operation and Development (OECD), from 2000 to 2014, the LAC region had an average output growth of 3% per year (OECD, 2016) - the region still suffers from a set of social-economic problems which enhance the gap between the LAC economies and the advanced (developed) ones. One of these "problems" is undoubtedly the high level of inequality that is frequently associated with this region (e.g. Gasparini and Lusting, 2011).

Following the "*World Social Report 2020*" from the United Nations (UN, 2020), the LAC stands as one of the regions with the highest income inequality, jointly with Africa. Given

this fact, it is not surprising that the progress of this region in terms of income inequality and its subsequent effects on the region's economies, be often analysed (e.g. Santiago et al., 2019; de la Torre et al., 2017; Delbianco, 2014).

Due to the increased attention that the income inequality subject has been receiving from international entities and scholars (e.g. Dabla-Norris et al., 2015; Piketty, 2013; OECD, 2011; Stiglitz, 2013), nowadays, there is a general view that governments should seriously invest in measures focused on the decrease of their countries income gaps. It is usually considered that this should be done not only to improve the standards of living of their populations but also to promote the macroeconomic stability of their nations.

Among the diverse tools that governments could use to decrease income inequality (e.g. fiscal policy, minimum wages, interest rate controls), government spending is often considered an important instrument to tackle income inequality (e.g. Anderson et al., 2017). Although most of the studies focus their analysis on the effects that the government spending on education, health, and social welfare have on income inequality (e.g. Martínez-Vázquez et al., 2012), there are other types of government spending whose effects on income inequality should be more intensively analysed (e.g. the public investment in infrastructure).

Following the International Monetary Fund (IMF, 2014), in the last three decades, the public capital stock as a share of output has been declining worldwide, which contributed to enlarging the gap between the infrastructure levels of developing and developed countries. Among the various negative effects that this situation can produce, there is the case of impacts that it can have on inequality, especially given that the public capital stock is directly related to the government's investment, namely in economic and social public infrastructures (IMF, 2017).

In the case of the LAC and according to Faruqee (2016), the lack of investment in infrastructures in the region has been compromising its competitiveness. In fact, According to the general opinion, nowadays, the LAC region suffers from an "infrastructure gap" which, if nothing is done, can be harmful to the economic sustainability and development of the LAC countries (Lardé and Sánchez, 2014; Perrotti, 2011). This situation is especially worrisome given that the failure to invest in infrastructure in LAC can be particularly harmful to the poorest strata of the population and prevent the region from joining the group of upper-income countries (Cavallo et al., 2020; Cavallo and Powell, 2019).

Following these previous statements, it is easy to perceive why it is important to study the relationship between these two variables (capital stock and income inequality) in the LAC. Due to the region's high inequality levels and its "*infrastructure gap*", it becomes mandatory to understand how these two problems are related. In the future, the investment that the region urgently needs can also be channelled to the mitigation of its income inequality levels.

As an advantage, one should also refer that with the release of the "*Investment and Capital Stock Dataset*" by the IMF (2017), data on public and private capital stocks became available for a large number of countries and years, thus allowing to extend the analyses focused on these variables to a vast number of countries and regions. Given its availability, the private capital stock should also be included in the analysis.

Hence, the central question of this chapter will be the following: Is the LAC capital stock (public and private) contributing to reduce the region's income inequality? To answer this question, the impact of public and private capital stock on income inequality will be examined using a dataset comprising 18 countries from the LAC region in the period from 1995 to 2017. The empirical estimation will be based on the use of the panel autoregressive distributed lag (PARDL) model in the form of an unrestricted error correction model (UECM), which allows decomposing the effects of the variables into their short- and long-run components.

Finally, this chapter will be organised as follows: Section 4.2 presents the literature review; Section 4.3 describes the data and methodology; Section 4.4 presents the empirical results and their respective discussion and Section 4.5 displays the conclusions and policy implications that can be drawn from this analysis.

4.2 Literature Review

Regarding the literature on the effects of the public capital stock on income inequality, it should be firstly stressed that there is a scarcity of literature that directly addresses these two subjects. Most of the public capital literature is focused on the relationship between this variable and economic growth (e.g. De Jong et al., 2018; Romp and De Haan, 2007).

However, if one considers the public capital stock as a form of government spending (i.e. public investment) or as a variable that mostly represents the public provision of infrastructure, the number of studies from which one can draw information significantly increases. This allows shedding some light on the relationship between these two variables.

In general, public investment is seen as a valuable tool to struggle against inequality. The outcomes of several studies show that increases in public investment levels can, in fact, lead to a more equal distribution of income (e.g., Bom and Goti, 2018; Furceri and Li, 2017). However, as in the case of the relationship between public investment and growth, the magnitude of this effect can be influenced by numerous factors as, for example, the countries investment efficiency, the way that they finance their public investment, and their degree of economic slack (IMF, 2014).

Again, it is important to note that public investment can take several forms. One of these forms is the government's investment in physical capital. More properly, the government's investment in physical assets as, for example, roads, railways, bridges, schools, hospitals, sanitation and water systems, telecommunications, energy systems, among others.

According to the literature review conducted by Calderón and Servén (2014), the effects of public infrastructure and infrastructure in general on income inequality seem to be similar to those from the public investment-income inequality relationship. This means that most results point to the idea that infrastructure development tends to reduce income inequality. However, there is a lower number of authors whose results seem to support the opposite effect (e.g. Turnovsky 2015; Chatterjee and Turnovsky, 2012).

The major problem with the literature devoted to this relationship is, indeed, the lack of knowledge regarding the channels through which these effects act. Still, some authors have presented some explanations regarding the possible channels by which infrastructure can affect income distribution.

As an example, several authors have stated that the investment in infrastructure can decrease income inequality by the fact that it can be a vital help to link the poorest/rural areas to the richer areas where there is a more thriving economic activity (Calderón and Servén, 2014; Calderón and Servén, 2004; Calderón and Chong, 2004; Estache, 2003; Lopez, 2003). More precisely, it can reduce production and transportation costs, facilitate information flows, and increase access to further productive opportunities. However, Lopez (2003) states that if the infrastructure investments are channelised to the already rich/developed areas, then they can produce an enhancing effect on inequality.

Moreover, there are also authors who pointed the positive effects that increased physical and social infrastructure investment can have on human capital as another channel

through which the investment in infrastructure can contribute to attenuate inequality (e.g. Calderón and Servén, 2014; Agenor and Moreno-Dodson, 2006). Following their conclusions, these positive effects on human capital can lead to the enhancement of productivity, better earnings, and improved social welfare.

Additionally, according to Pi and Zhou (2012), an increased supply of public infrastructure raises the marginal productivity of both the skilled and unskilled labour, which, consequently, raises their earnings. If the sector which is more intensive in public infrastructure services is the one that uses unskilled labour, the skilled-unskilled wage inequality will be reduced due to the capital shift from the skilled to the unskilled sector. Although, if the sector which is more intensive in public infrastructure is the one using skilled labour, the effect will be the opposite.

According to Easterly and Servén (2003), several countries have increasingly reduced their public investment in infrastructure due to pressures associated with fiscal consolidation. This fact has led to a state of an insufficient provision in many of these cases. Following these authors, even with the increased participation from the private sector, the provision remained far from being sufficient, negatively affecting both growth and equity.

This can be the case of the LAC countries that, due to the debt crisis of the 1980s, have seen their public investment levels being progressively reduced in the following decades. Even today, the levels of public investment in these countries remain relatively low, raising several concerns about the potential adverse effects of this gap on the region's development (see, e.g. Castellani et al., 2019).

Relatively to private capital, it should be referred that in many countries, the private sector has massive participation in the provision of infrastructure. Indeed, governments often choose to privatise determined infrastructure sectors rather than investing themselves. This fact can produce several different effects on income distribution.

Starting with the “employment effects”, Estache et al. (2002) state that after privatisation, the formerly public companies usually become profitable. This is mainly due to the downsizing strategy, which is usually followed by the new private providers. The effect of the downsizing on income distribution depends on the number of lower-income workers in the infrastructure sector and on the compensation to the workers who were laid off during the downsizing process. Benitez et al. (2001) imply that if the new private investment in infrastructure fosters growth and new jobs, the effects of the

downsizing process in the public infrastructure sector (i.e. fewer jobs in the public sector) can be compensated by the creation of jobs in other sectors.

Apart from these effects, increased private participation can also eradicate subsidies to infrastructure provision and generate additional public revenues from privatisation. If these fiscal resources are used to improve the quality and efficiency of public services, they can lead to a reduction in income inequality (Estache et al., 2000).

However, following Estache et al. (2002), privatisation of infrastructure services can also lead to the creation of barriers in the access and affordability of these services by the poor due to market effects. The elimination of subsidies may lead to higher prices, private providers may charge more significant connection fees than public providers, and the private initiative may be unwilling to invest in the poorest/undeveloped areas. These facts can lead to that infrastructure services become too expensive for the lower-income groups, thus increasing the gap between the poor and the rich.

This previous idea is in accordance with Ferreira (1995), who pointed the fact that credit constraint faced by the poor eventually inhibits them from using the private substitutes for infrastructure, whereas the rich can complement the public provision of infrastructure with the private alternatives. However, as is stressed by Calderón and Servén (2014), the effects of the privatisation of infrastructure services on the poor are extremely dependent on the design of the reforms of the infrastructure sector involving private participation.

Finally, concerning the econometric approach of the past studies, most authors used panel data methods and estimators capable of dealing with potential endogeneity problems (e.g. Seneviratne and Yan Sun, 2013; Calderón and Servén, 2004; Calderón and Chong, 2004). Following Seneviratne and Yan Sun (2013, p. 9), this endogeneity problem arises from the fact that "*income inequality could prevent the poor from accessing infrastructure services, while at the same time inadequate infrastructure may worsen income inequality*".

4.3 Data and Methodology

To accomplish the goals of this chapter, annual data was collected from 1995 to 2017 for a panel of 18 LAC countries. These LAC countries were Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela.

As in the case of the previous chapter, both countries and time horizon were chosen according to the data availability, with the econometric analysis being conducted through the use of the Stata 15 statistical software. The name, definition, and sources, of the raw variables, are displayed in Table 4.1.

Table 4.1 – Variables description

Variable	Definition	Source
INEQ	Gini index	Standardized World Income Inequality Database
KPUB	General government capital stock (current cost), in billions of national currency	Investment and Capital Stock Dataset
KPRIV	Private capital stock (current cost), in billions of national currency	Investment and Capital Stock Dataset
K	Capital stock (current cost), in billions of national currency	Authors own calculations
Y	Gross domestic product (current prices), in billions of national currency	Investment and Capital Stock Dataset
HDI	Human development index	Human Development Reports
TRD	Trade (% of GDP)	World Development Indicators
TR	Tax revenue (% GDP)	CEPALSTAT
UNP	Unemployment, total (% of the total labour force)	World Development Indicators
CPI	Annual consumer prices indices general level (Base Index 2010=100)	CEPALSTAT

The dependent variable will be represented by the Gini index of disposable income (INEQ). This variable was collected from the "*Standardized World Income Inequality Database*" (SWIID) (Solt, 2020) and will be the measure of income inequality. The values of this index range from 0% to 100%, with 0% representing perfect equality and 100% representing maximum inequality.

The option for the SWIID index was mainly due to the amount of available data that this database had when compared with alternative sources. Moreover, the option to use the Gini index of disposable income rather than market income was due to the fact that the first one is related to the income after taxes and transfers, thus being closer to the value that individuals have for spending and saving.

Concerning the interest variables of the models, they will be (1) capital stock (K) in Model I; (2) general government capital stock or public capital stock (KPUB) in Model II; and (3) private capital stock (KPRIV) in Model III. As it could be perceived, the variable capital stock (K) is the sum of both types of capital, public (KPUB) and private (KPRIV).

The public capital stock (KPUB) and the private capital stock (KPRIV) were both retrieved from the "*Investment and Capital Stock Dataset*" (IMF, 2017).

It is also important to stress that the variable consumer prices indices (CPI) – retrieved from the CEPALSTAT - was used to transform the variables capital stock (K), public capital stock (KPUB), private capital stock (KPRIV), and gross domestic product (Y) into their real values (or constant values). In other words, it was used to adjust the variables to the effects of price changes. Finally, after this adjustment, the variables capital stock (K), public capital stock (KPUB) and private capital stock (KPRIV) were then transformed into percentages of the GDP.

The remaining variables, i.e. the control variables of the models, will be some of the numerous variables which are commonly used on income inequality regressions. Again, one warns that among the full range of variables that could be used, the control variables that were chosen were those for which a considerable amount of data was available.

The variables that were chosen were: (1) gross domestic product (Y) from the "*Investment and Capital Stock Dataset*"; (2) human development index (HDI) from the United Nations "*Human Development Reports*"; (3) trade-in percentage of the gross domestic product (TRD) from the "*World Development Indicators*" of the World Bank; (4) tax revenue in the percentage of the gross domestic product (TR) from the CEPALSTAT; and (5) unemployment rate in percentage of the total labour force (UNP) from the "*World Development Indicators*" of the World Bank.

Still, concerning the control variables, there are a vast number of theoretical and empirical evidence that leads to the belief that all these variables can influence income inequality. First, regarding the gross domestic product (Y), one can say that the relationship between this variable and income inequality has aroused the interest of researchers for several decades. In fact, the nexus between growth and income inequality is the subject of many past and present studies (e.g. Yang and Greaney, 2017; Rubin and Segal, 2015). As an example, Tsounta and Osueke (2014) found that after policy measures, economic growth was the main reason for the decrease in income inequality in Latin America.

Regarding the human development index (HDI), it should be stressed that most authors focused their investigations on the effects of education on income inequality (e.g. Coady and Dizioli, 2018). However, as most of the education variables have some problems related to the lack of data, in this analysis it was used the HDI. In addition to taking

education into account, HDI also incorporates data related to population health and living standards. Theyson and Heller (2015), for example, investigated the relationship between development (proxied by HDI) and income inequality and found that human development could have different effects on income inequality, depending on the development stage of the countries.

Concerning trade (TRD), the vast literature that addresses its relationship with income inequality has found mixed results (e.g. Cerdeiro and Komaromi, 2017; Urata and Narjoko, 2017; Meschi and Vivarelli, 2009). However, Cerdeiro and Komaromi (2017), who developed a study to be included in an IMF report on trade integration in the LAC, found that trade tends to have a reducing effect on income inequality.

When it comes to tax revenue (TR), there is a wide range of studies that are focused on the effects of tax policies on income inequality (e.g. Martorano, 2018; Balseven and Tugcu, 2017; Sabaíni et al., 2016; Bird and Zolt, 2005). Following the results of Balseven and Tugcu (2017), tax revenue can contribute to the decrease in income inequality in developing economies, while according to Martorano (2018), the low levels of tax revenue from the Latin American (LA) countries can indeed be an obstacle to the promotion of equality in this region.

Finally, concerning the unemployment rate (UNP), there is also extensive literature that addresses the relationship between this macroeconomic indicator and income inequality (e.g. Sheng, 2011; Helpman et al., 2010; Cysne, 2009; Mocan, 1999). The overall conclusion is that the unemployment rate has an augmenting effect on income inequality. Following Gasparini and Lusting (2011), unemployment could have contributed to the rising inequality in Argentina due to its indirect effect on wages. Moreover, Hacibedel et al. (2019) conclude that policies to support employment are an essential tool for reducing inequality in emerging market countries and low-income countries, with their regressions showing that increases in unemployment tend to boost inequality, regardless of whether the countries are facing a “good” or “bad“ economic conjuncture.

Regarding the empirical analysis and its methodology, it was based on the PARDL model in the form of a UECM. There are several advantages for using this model: first, it allows to identify the short- and long-run impacts of the explanatory variables on the dependent variable; second, it deals appropriately with cointegration; third, it allows the inclusion of I(0), I(1), and fractionally integrated variables in the same estimation; fourth, is robust

when there are signals of endogeneity; and, fifth, it gives consistent results with a small/moderate number of observations.

Equations (4.1), (4.2), and (4.3) represent the PARDL specifications of the three models. Again, Model I with total capital stock (K) as the interest variable, Model II with the general government capital stock (KPUB) as the interest variable and, finally, Model III with private capital stock (KPRIV) as the interest variable. The variables are represented in natural logarithms (with the prefix "L") and first differences (with the prefix "D").

$$\begin{aligned} LINEQ_{it} =& \alpha_{1i} + \beta_{1i1} LINEQ_{it-1} + \beta_{1i2} LK_{it} + \beta_{1i3} LK_{it-1} + \\ & \beta_{1i4} LY_{it} + \beta_{1i5} LY_{it-1} + \beta_{1i6} LHDI_{it} + \beta_{1i7} LHDI_{it-1} + \beta_{1i8} LTRD_{it} + \beta_{1i9} LTRD_{it-1} + \\ & \beta_{1i10} LTR_{it} + \beta_{1i11} LTR_{it-1} + \beta_{1i12} LUNP_{it} + \beta_{1i13} LUNP_{it-1} + \varepsilon_{1it} \end{aligned} \tag{4.1}$$

$$\begin{aligned} LINEQ_{it} =& \alpha_{2i} + \beta_{2i1} LINEQ_{it-1} + \beta_{2i2} LKPUB_{it} + \beta_{2i3} LKPUB_{it-1} + \\ & \beta_{2i4} LY_{it} + \beta_{2i5} LY_{it-1} + \beta_{2i6} LHDI_{it} + \beta_{2i7} LHDI_{it-1} + \beta_{2i8} LTRD_{it} + \beta_{2i9} LTRD_{it-1} + \\ & \beta_{2i10} LTR_{it} + \beta_{2i11} LTR_{it-1} + \beta_{2i12} LUNP_{it} + \beta_{2i13} LUNP_{it-1} + \varepsilon_{2it} \end{aligned} \tag{4.2}$$

$$\begin{aligned} LINEQ_{it} =& \alpha_{3i} + \beta_{3i1} LINEQ_{it-1} + \beta_{3i2} LKPRIV_{it} + \beta_{3i3} LKPRIV_{it-1} + \beta_{3i4} LY_{it} + \\ & \beta_{3i5} LY_{it-1} + \beta_{3i6} LHDI_{it} + \beta_{3i7} LHDI_{it-1} + \beta_{3i8} LTRD_{it} + \beta_{3i9} LTRD_{it-1} + \\ & \beta_{3i10} LTR_{it} + \beta_{3i11} LTR_{it-1} + \beta_{3i12} LUNP_{it} + \beta_{3i13} LUNP_{it-1} + \varepsilon_{3it} \end{aligned} \tag{4.3}$$

To obtain the dynamic relations between the variables, i.e. the dynamic general UECM form of the PARDL model, the Equations (4.1), (4.2), and (4.3), can be reparametrized into the Equations (4.4), (4.5), and (4.6), as follows:

$$\begin{aligned} DLINEQ_{it} =& \alpha_{4i} + \beta_{4i1} DLK_{it} + \beta_{4i2} DLY_{it} + \beta_{4i3} DLHDI_{it} + \beta_{4i4} DLTRD_{it} + \\ & \beta_{4i5} DLTR_{it} + \beta_{4i6} DLUNP_{it} + \gamma_{4i1} LINEQ_{it-1} + \gamma_{4i2} LK_{it-1} + \gamma_{4i3} LY_{it-1} + \\ & \gamma_{4i4} LHDI_{it-1} + \gamma_{4i5} LTRD_{it-1} + \gamma_{4i6} LTR_{it-1} + \gamma_{4i7} LUNP_{it-1} + \varepsilon_{4it} \end{aligned} \tag{4.4}$$

$$\begin{aligned} DLINEQ_{it} =& \alpha_{5i} + \beta_{5i1} DLKPUB_{it} + \beta_{5i2} DLY_{it} + \beta_{5i3} DLHDI_{it} + \beta_{5i4} DLTRD_{it} + \\ & \beta_{5i5} DLTR_{it} + \beta_{5i6} DLUNP_{it} + \gamma_{5i1} LINEQ_{it-1} + \gamma_{5i2} LKPUB_{it-1} + \gamma_{5i3} LY_{it-1} + \\ & \gamma_{5i4} LHDI_{it-1} + \gamma_{5i5} LTRD_{it-1} + \gamma_{5i6} LTR_{it-1} + \gamma_{5i7} LUNP_{it-1} + \varepsilon_{5it} \end{aligned} \tag{4.5}$$

$$DLINEQ_{it} = \alpha_{6i} + \beta_{6i1}DLKPRIV_{it} + \beta_{6i2}DLY_{it} + \beta_{6i3}DLHDI_{it} + \beta_{6i4}DLTRD_{it} + \beta_{6i5}DLTR_{it} + \beta_{6i6}DLUNP_{it} + \gamma_{6i1}LINEQ_{it-1} + \gamma_{6i2}LKPRIV_{it-1} + \gamma_{6i3}LY_{it-1} + \gamma_{6i4}LHDI_{it-1} + \gamma_{6i5}LTRD_{it-1} + \gamma_{6i6}LTR_{it-1} + \gamma_{6i7}LUNP_{it-1} + \varepsilon_{6it} \quad (4.6)$$

In the Equations (4.4), (4.5), and (4.6), the α_i represents the intercept, while β_{ik} and γ_{ik} represent the estimated parameters, with k = 1, ..., 7. The ε_{it} denotes the error term.

In order to choose a suitable estimator for the three models, there is a need to conduct a series of preliminary tests and specification tests before the estimation. Hence, to understand the characteristics of the series and cross-sections, the following preliminary tests were applied:

- the correlation matrix;
- the variance inflation factor (VIF) (Belsley et al. 1980);
- the cross-sectional dependence (CD) test (Pesaran, 2004);
- the cross-sectionally augmented Im, Pesaran and Shin (CIPS) (Pesaran, 2007).

The correlation matrices and VIF statistics results can be seen in Tables 4.2 (with the variables in natural logarithms) and 4.3 (with the variables in first differences).

Table 4.2 – Correlation matrices and VIF statistics (variables in natural logarithms)

Model I							
	LINEQ	LK	LY	LHDI	LTRD	LTR	LUNP
LINEQ	1.0000						
LK	0.0668	1.0000					
LY	0.0842	-0.1239	1.0000				
LHDI	-0.4848	-0.3087	0.3306	1.0000			
LTRD	0.0772	-0.0131	-0.2605	-0.2374	1.0000		
LTR	-0.3300	-0.1116	-0.0546	0.1739	0.0059	1.0000	
LUNP	-0.1554	0.1943	0.4369	0.3069	-0.4691	0.0228	1.0000
VIF		1.33	1.37	1.42	1.31	1.06	1.74
Mean VIF		1.37					
Model II							
	LINEQ	LKPUB	LY	LHDI	LTRD	LTR	LUNP
LINEQ	1.0000						
LKPUB	-0.1155	1.0000					
LY	0.0842	-0.2221	1.0000				
LHDI	-0.4848	-0.4016	0.3306	1.0000			
LTRD	0.0772	-0.0070	-0.2605	-0.2374	1.0000		
LTR	-0.3300	0.1344	-0.0546	0.1739	0.0059	1.0000	
LUNP	-0.1554	0.0848	0.4369	0.3069	-0.4691	0.0228	1.0000
VIF		1.42	1.38	1.57	1.32	1.10	1.64
Mean VIF		1.40					
Model III							
	LINEQ	LKPRIV	LY	LHDI	LTRD	LTR	LUNP
LINEQ	1.0000						
LKPRIV	0.3135	1.0000					
LY	0.0842	0.0527	1.0000				
LHDI	-0.4848	-0.1141	0.3306	1.0000			
LTRD	0.0772	-0.0033	-0.2605	-0.2374	1.0000		
LTR	-0.3300	-0.3703	-0.0546	0.1739	0.0059	1.0000	
LUNP	-0.1554	0.1173	0.4369	0.3069	-0.4691	0.0228	1.0000
VIF		1.24	1.33	1.24	1.31	1.24	1.56
Mean VIF		1.32					

Notes: In the case of the VIF test, the values are lower than the typically assumed benchmarks: 10 in the case of the VIF values, and 6 in the case of the mean VIF values; the Stata commands *corr* and *estat vif* were used to compute the correlation matrix and VIF statistics, respectively.

Table 4.3 – Correlation matrices and VIF statistics (variables in first differences)

Model I							
	DLINEQ	DLK	DLY	DLHDI	DLTRD	DLTR	DLUNP
DLINEQ	1.0000						
DLK	0.1476	1.0000					
DLY	-0.1873	-0.4421	1.0000				
DLHDI	0.0050	-0.2882	0.2392	1.0000			
DLTRD	0.0633	-0.0821	0.0702	0.0791	1.0000		
DLTR	0.0168	-0.0643	-0.0634	0.1182	0.2035	1.0000	
DLUNP	0.1913	0.2685	-0.2359	-0.1109	-0.2072	-0.1900	1.0000
VIF		1.48	1.37	1.11	1.08	1.11	1.22
Mean VIF		1.23					
Model II							
	DLINEQ	DLKPUB	DLY	DLHDI	DLTRD	DLTR	DLUNP
DLINEQ	1.0000						
DLKPUB	0.1099	1.0000					
DLY	-0.1873	-0.4097	1.0000				
DLHDI	0.0050	-0.2932	0.2392	1.0000			
DLTRD	0.0633	-0.0653	0.0702	0.0791	1.0000		
DLTR	0.0168	-0.0503	-0.0634	0.1182	0.2035	1.0000	
DLUNP	0.1913	0.2520	-0.2359	-0.1109	-0.2072	-0.1900	1.0000
VIF		1.40	1.31	1.12	1.08	1.11	1.21
Mean VIF		1.20					
Model III							
	DLINEQ	DLKPRIV	DLY	DLHDI	DLTRD	DLTR	DLUNP
DLINEQ	1.0000						
DLKPRIV	0.1783	1.0000					
DLY	-0.1873	-0.4433	1.0000				
DLHDI	0.0050	-0.2772	0.2392	1.0000			
DLTRD	0.0633	-0.0842	0.0702	0.0791	1.0000		
DLTR	0.0168	-0.0767	-0.0634	0.1182	0.2035	1.0000	
DLUNP	0.1913	0.2677	-0.2359	-0.1109	-0.2072	-0.1900	1.0000
VIF		1.47	1.37	1.10	1.08	1.12	1.22
Mean VIF		1.23					

Notes: In the case of the VIF test, the values are lower than the typically assumed benchmarks: 10 in the case of the VIF values, and 6 in the case of the mean VIF values; the Stata commands *corr* and *estat vif* were used to compute the correlation matrix and VIF statistics, respectively.

From the results displayed in Table 4.2 and 4.3, both collinearity and multicollinearity are far from being a concern to the estimations of the three models, given the low correlation and VIF (and Mean VIF) values. In the case of the VIF test, the values are lower than the typically assumed benchmarks: 10 in the case of the VIF values and 6 in the case of the mean VIF values.

The descriptive statistics of the variables in natural logarithms and first differences are now displayed in Table 4.4, together with the results from the cross-sectional dependence test. Before analysing the outcomes from the cross-sectional dependence test, it should be stressed that the variables INEQ, K, KPUB, KPRIV, Y, and TRD, have fewer observations.

There was a lack of observations for the Gini index of disposable income (INEQ) in the cases of the Dominican Republic in 2017, Guatemala in 2015, 2016, and 2017, Mexico in

2017, Nicaragua in 2015, 2016, and 2017, and Venezuela in 2016 and 2017. Venezuela also has a shortage of data for the total capital stock (K), public capital stock (KPUB), and private capital stock (KPRIV) in 2016 and 2017, and for trade in the percentage of the gross domestic product (TRD) in 2015, 2016, and 2017.

Despite the previously mentioned facts, the statistical software Stata 15 still assumes the panel as a "strongly balanced" one, given that the lack of data only occurs at the end of the series. This outcome seems to indicate that the analysis can continue without significant concerns.

Table 4.4 – Descriptive statistics and CD-test

Variables	Descriptive statistics					Cross-sectional dependence test		
	Obs.	Mean	Std. Dev.	Min.	Max.	CD-test	Corr.	Abs. (corr.)
LINEQ	404	3.8300	0.0888	3.5807	3.9722	38.21***	0.660	0.813
LK	412	5.4820	0.2396	4.9834	6.7567	6.03***	0.105	0.443
LKPUB	412	4.1555	0.5827	3.0219	6.2561	6.94***	0.121	0.501
LKPRIV	412	5.1201	0.2259	4.4146	5.8248	5.21***	0.091	0.464
LY	412	7.1069	2.8219	2.5355	13.4472	46.79***	0.808	0.868
LHDI	414	-0.3746	0.1064	-0.6792	-0.1708	56.73***	0.979	0.979
LTRD	411	4.0617	0.4563	2.7496	5.1162	15.54***	0.264	0.462
LTR	414	2.5375	0.2502	1.7138	3.0958	27.21***	0.460	0.523
LUNP	414	1.7724	0.4911	0.6966	3.0214	14.48***	0.248	0.467
DLINEQ	386	-0.0051	0.0095	-0.0376	0.0219	17.69***	0.310	0.369
DLK	394	0.0000	0.0735	-0.2488	0.8455	11.40***	0.200	0.277
DLKPUB	394	-0.0043	0.0757	-0.2454	0.8520	8.66***	0.151	0.266
DLKPRIV	394	0.0024	0.0743	-0.2536	0.8357	12.51***	0.220	0.277
DLY	394	0.0327	0.0778	-0.7740	0.2635	16.82***	0.295	0.315
DLHDI	396	0.0072	0.0058	-0.0117	0.0429	6.51***	0.115	0.220
DLTRD	393	0.0027	0.0946	-0.3371	0.6475	20.87***	0.363	0.377
DLTR	396	0.0111	0.0805	-0.7910	0.2923	6.04***	0.104	0.207
DLUNP	396	-0.0085	0.1302	-0.4742	0.4783	11.38***	0.199	0.247

Notes: Obs., Observations; Std. Dev., Standard Deviation; Min., Minimum, Max, Maximum; Corr., Correlation; Abs. (corr.), Absolute Correlation; the CD-test has N (0,1) distribution under the H0: cross-section independence; *** denotes statistical significance at 1% and 5% level, respectively; the Stata commands *sum* and *xtcd* were used to compute the descriptive statistics and the CD-test, respectively.

Regarding the cross-sectional dependence test, the results (Table 4.4) endorse the presence of cross-sectional dependence in all the variables, either in natural logarithms as in first differences. This suggests that there is interdependence between variables across countries, maybe due to the mutual shocks that the countries share. Thus, there is the need to account for this phenomenon in the estimation, or else, incorrect inferences may be produced (see Eberhardt and Teal, 2011).

Given the cross-sectional dependence test results, the second-generation unit root test, also known as CIPS, was computed in order to access the order of integration of the variables. The reason to not use the first generation panel unit root tests, as the Levin, Lin and Chu (LLC) (Levin et al., 2002), the Augmented Dickey-Fuller (ADF) - Fisher (Maddala and Wu, 1999) and the ADF-Choi (Choi, 2001) is that these tests do not

account for cross-sectional dependence. Conversely, the second-generation unit root tests, as the CIPS, take this phenomenon into account. The results of the CIPS test are displayed in Table 4.5.

Table 4.5 – CIPS test

	CIPS (Zt-bar)	
	without trend	With trend
LINEQ	-0.232	-1.774**
LK	2.187	2.870
LKPUB	1.417	1.090
LKPRIV	3.586	3.638
LY	1.402	1.218
LHDI	-0.503	1.136
LTRD	-0.946	0.601
LTR	-1.042	0.022
LUNP	0.182	1.710
DLINEQ	-3.439***	-1.741**
DLK	-3.441***	-1.968**
DLKPUB	-3.362***	-1.729**
DLKPRIV	-3.004***	-2.142**
DLY	-5.570***	-4.414***
DLHDI	-5.152***	-3.649***
DLTRD	-4.883***	-3.218***
DLTR	-6.688***	-5.486***
DLUNP	-3.558***	-0.897

Notes: *** and **, denote statistical significance at the 1% and 5% level, respectively; CIPS assumes that cross-sectional dependence is in the form of a single unobserved common factor and H0: series is I(1); the Stata command *multipurt* was used to compute this test.

The outcomes from the CIPS test (Table 4.5) seem to indicate that all variables in natural logarithms are I(1), i.e. they are integrated of order one, and that they are all stationary in first differences, except DLUNP with the trend. Given this issue, a time trend was not included in the models.

After the performance of the preliminary tests and the subsequent analysis of their results, the next step will be the computation of a battery of specifications tests. The results from these tests will allow selecting a suitable estimator for the three models.

4.4 Results and Discussion

As it was previously mentioned, before the estimation of the models, there is the need to test for the presence of several effects and phenomena which, if not considered, can lead to misleading conclusions. In the case of this analysis, the specification tests which were conducted were the following:

- the Hausman test (Hausman, 1978) to confront the random effects (RE) and fixed effects (FE) models;

- the Hausman test (Hausman, 1978) to confront the mean group (MG), the pooled mean group (PMG), and the pooled estimators;
- the modified Wald test (Greene, 2002);
- the Pesaran test of cross-sectional independence (Pesaran, 2004);
- the Frees' test of cross-sectional independence (Frees, 2004, 1995);
- the Friedman's test of cross-sectional independence (Friedman, 1937);
- the Wooldridge test (Wooldridge, 2002).

The results from the Hausman tests between the random effects (RE) and fixed effects (FE) models are presented in Table 4.6. The test's null hypothesis is that the difference in coefficients is not systematic or that the random effects (RE) are the most suitable specification. In general, the results of these tests allow perceiving if the countries individual effects must be considered.

Table 4.6 – Hausman tests (FE vs. RE)

	Model I	Model II	Model III
	FE vs. RE	FE vs. RE	FE vs. RE
Hausman test	Chi2(13) = 82.87***	Chi2(13) = 86.39***	Chi2(13) = 81.90***
Hausman test (with *sigmamore*)	Chi2(13) = 75.22***	Chi2(13) = 81.81***	Chi2(13) = 73.37***
Hausman test (with *sigmaless*)	Chi2(13) = 91.04***	Chi2(13) = 101.29***	Chi2(13) = 88.26***

Notes: *** denotes significance at the 1% level; Ho: difference in coefficients not systematic/RE is preferable; the Stata command h*ausman* (with and without the *sigmamore* and *sigmaless* options) was used to compute this test.

It is important to refer that as in the standard specification, "*the covariance matrix has not been positively defined*", the *sigmamore* and *sigmaless* options were used to overcome this situation. This can also be considered as a robustness test to the standard Hausman test result.

Following the results from Table 4.6, the null hypothesis is rejected for all specifications (with the standard specification and with the *sigmamore* and *sigmaless* options). Due to this fact, the conclusion is that the FE is the most suitable specification, i.e. the individual effects should be accounted for. This conclusion is extended to all three models.

The next step of the estimation was to confront the MG, the PMG, and the pooled estimators to test the parameters' slope heterogeneity. In other words, to inquire about the homogeneity/heterogeneity of the panel.

On the one hand, contrary to the FE, the MG estimator (Pesaran and Smith, 1995) computes separated equations for each of the crosses (computing an average coefficient for all individuals) and has no restrictions concerning the homogeneity of the long-run coefficients. On the other hand, the PMG estimator (Pesaran et al., 1999) combines the "*pooling*" of the FE estimator with the "*averaging*" of the MG estimator, allowing differences in the error variances, short-run coefficients, the speed of adjustment, and intercept.

However, the PMG imposes the homogeneity restriction on the long-run coefficients, and so, if homogeneity is detected in the long-run, the PMG should be more consistent than the MG (Pesaran et al., 1999). For a more profound discussion on the MG and PMG estimators, see Pesaran et al. (1999).

Usually, to compare the MG, PMG, and FE, one would use the *xtpmg* (Blackburne and Frank, 2007) Stata command. This command allows to compute the models with each of these estimators and then confront them recurring to the Hausman test. However, the command *xtpmg* presented some errors that did not allow estimating the PMG correctly.

In order to overcome the previous problem, there was the need to recur to an alternative command: the *xtdcce2* (Ditzen, 2018). This command also allows to compute MG and PMG estimations, but instead of the FE estimation (as in the *xtpmg*), it allows to compute a Pooled estimation. Nevertheless, given that the FE and RE estimators are considered "traditional pooled estimators" (Pesaran et al., 1999, p. 621), the Hausman tests indicate the Pooled as the preferable estimator, the analysis will proceed with the FE. The results from the Hausman tests between these estimators are displayed in Table 4.7.

Table 4.7 – Hausman tests (MG vs PMG vs Pooled)

	Model I	Model II	Model III
Hausman test	MG vs. PMG	MG vs. PMG	MG vs. PMG
	Chi2(13) = -58.61	Chi2(13) = 60.14***	Chi2(13) = 31.81***
	PMG vs Pooled	PMG vs Pooled	PMG vs Pooled
	Chi2(13) = 0.19	Chi2(13) = 7.39	Chi2(13) = 0.75
	MG vs Pooled	MG vs Pooled	MG vs Pooled
	Chi2(13) = -7.76	Chi2(13) = 15.54	Chi2(13) = -1.14

Notes: *** denotes statistically significant at 1%; H0: difference in coefficients not systematic; to compute this test, the Stata commands *xtdcce2* and h*ausman* were used.

The null hypotheses of these Hausman tests are that the difference in coefficients is not systematic or that: (1) the pooled mean group (PMG) is the most suitable (when MG vs PMG); (2) Pooled is the most suitable (when PMG vs Pooled and MG vs Pooled). In addition, according to the "*Hausman specification test*" from the Stata Manual[1] (p. 8), it is also important to stress the fact that the negative "*Chi2*" values can be interpreted "*as strong evidence that we cannot reject the null hypothesis*".

Looking at the results from the Hausman tests in Table 4.7, it seems that the Pooled estimator is the most suitable for all models. This suggests that the panel is indeed homogeneous, allowing these countries to be treated as a group. Given this conclusion, the estimation of the models will proceed with the FE rather than with the MG and PMG.

In Table 4.8, the outcomes from the remaining specification tests are presented. These are: (1) the modified Wald test, to test for group-wise heteroscedasticity; (2) the Pesaran, Frees, and Friedman tests of cross-sectional independence, to test for the presence of contemporaneous correlation among cross-sections; and (3) the Wooldridge test, to test for the presence of serial correlation. The null hypotheses of these tests are, respectively: (1) sigma(i)^2= sigma^2 (or no group-wise heteroscedasticity); (2) residuals are not correlated (or no contemporaneous correlation); and (3) no first-order autocorrelation (or no serial correlation).

The Breusch and Pagan Lagrangian Multiplier (LM) test of independence (Breusch and Pagan, 1980) was also computed. However, as the correlation matrix of residuals was singular, it could not produce any outcome. Nevertheless, the Pesaran, Frees, and Friedman tests of cross-sectional independence can be seen as alternatives to this test.

[1]Available at: https://www.stata.com/manuals/rhausman.pdf.

Table 4.8 – Specification tests

	Model I	Model II	Model III
	Statistics	Statistics	Statistics
Modified Wald test	141.08***	144.96***	139.46***
Pesaran's test	2.939***	3.051***	2.868***
Frees' test	0.857***	0.878***	0.847***
Friedman's test	30.705**	31.267**	30.105**
Wooldridge test	19.286***	19.482***	19.193***

Notes: ** and *** denote statistical significance at 5% and 1% level, respectively; H0 of Modified Wald test: sigma(i)^2= sigma^2 for all I; H0 of Pesaran's, Frees', and Friedman's: residuals are not correlated; H0 of Wooldridge test: no first-order autocorrelation; to compute these tests, the Stata commands *xttest3*, *xtcsd*, *xtserial* were used, respectively.

The results displayed in Table 4.8 show that all null hypotheses from the specification tests are rejected for all models. This means that heteroscedasticity, contemporaneous correlation, and first-order autocorrelation are all present in Model I, Model II, and Model III.

To deal with the presence of these phenomena (heteroskedasticity, contemporaneous correlation, first-order autocorrelation, and cross-sectional dependence), the Driscoll and Kraay (1998) estimator (DK) with FE was used to perform the analysis of the three models. This option was related to the fact that this estimator produces standard errors robust to the disturbances being cross-sectionally dependent, heteroskedastic, and autocorrelated. The results from the estimation of Model I, Model II, and Model III with the DK-FE estimator are presented in Table 4.9.

Table 4.9 – PARDL estimation results

Dependent Variable: DLINEQ	Model I	Model II	Model III
Constant	0.3781***	0.3749***	0.3804***
DLK	0.0186**	-	-
DLKPUB	-	0.0146**	-
DLKPRIV	-	-	0.0205**
DLY	-0.0114**	-0.0137***	-0.0105*
DLHDI	0.0542	0.0546	0.0514
DLTRD	-0.0003	-0.0005	-0.0002
DLTR	-0.0034	-0.0039	-0.0029
DLUNP	0.0090**	0.0089***	0.0090**
LINEQ (-1)	-0.0880***	-0.0869***	-0.0874***
LK (-1)	-0.0002	-	-
LKPUB (-1)	-	0.0012	-
LKPRIV (-1)	-	-	-0.0013
LY (-1)	-0.0025*	-0.0029**	-0.0025*
LHDI (-1)	-0.0688***	-0.0653***	-0.0676***
LTRD (-1)	-0.0089***	-0.0090***	-0.0088***
LTR (-1)	-0.0138***	-0.0142***	-0.0138***
LUNP (-1)	0.0102***	0.0095***	0.0105***
Diagnostic statistics			
N	385	385	385
R^2	0.3562	0.3525	0.3599
F	F(13, 21) = 91.68***	F(13, 21) = 63.56***	F(13, 21) = 109.37***

Notes: ***, **, and * denote statistical significance at 1%, 5%, and 10% level, respectively; the Stata command *xtscc* was used to estimate the models.

Before proceeding with the analysis, it should first be clarified that the long-run elasticities are not shown in Table 4.9. These elasticities had to be calculated through a ratio between the long-run coefficients of the variables and the LINEQ coefficient, both lagged once, and then multiply this ratio by – 1.

In addition, it should be stressed that the coefficient of the variable LINEQ lagged once represents the error correction mechanism (ECM) term, i.e. the adjustment speed of the models. The long-run elasticities, the short-run impacts, and the adjustment speed of Model I, Model II, and Model III are displayed in Table 4.10.

Table 4.10 – Elasticities, short-run impacts, and speed of adjustment

Dependent Variable: DLINEQ	Model I	Model II	Model III
Short-run impacts			
DLK	0.0186**	-	-
DLKPUB	-	0.01455**	-
DLKPRIV	-	-	0.0205**
DLY	-0.0114**	-0.0137***	-0.0105*
DLHDI	0.0542	0.0546	0.0514
DLTRD	-0.0003	-0.0005	-0.0002
DLTR	-0.0034	-0.0039	-0.0029
DLUNP	0.0090**	0.0089***	0.0089**
Long-run (computed) elasticities			
LK (-1)	-0.0025	-	-
LKPUB (-1)	-	0.0143	-
LKPRIV (-1)	-	-	-0.0144
LY (-1)	-0.0286**	-0.0337**	-0.0284*
LHDI (-1)	-0.7824***	-0.7505***	-0.7730***
LTRD (-1)	-0.1009***	-0.1031***	-0.1006***
LTR (-1)	-0.1573***	-0.1638***	-0.1574***
LUNP (-1)	0.1160***	0.1091***	0.1199***
Speed of adjustment			
ECM	-0.0880***	-0.0870***	-0.0874***

Notes: ***, and ** denote statistical significance at 1% and 5% level, respectively; the ECM denotes the coefficient of the variable LINEQ lagged once.

Following the rule of parsimony, after the first estimations, the variables that did not produce any statistically significant coefficients in the short- and long-run were removed. Namely the variables human development index (HDI), trade (TRD) and tax revenue (TR) from the short-run in all of the three models, and the variables total capital stock (K), public capital stock (KPUB), and private capital stock (KPRIV) from the long-run in Model I, Model II, and Model III, respectively. Now, the specifications from Equations (4.4), (4.5), and (4.6) can be replaced for:

$$DLINEQ_{it} = \alpha_{7i} + \beta_{7i1}DLK_{it} + \beta_{7i2}DLY_{it} + \beta_{7i3}DLUNP_{it} + \gamma_{7i1}LINEQ_{it-1} + \gamma_{7i2}LY_{it-1} + \gamma_{7i3}LHDI_{it-1} + \gamma_{7i4}LTRD_{it-1} + \gamma_{7i5}LTR_{it-1} + \gamma_{7i6}LUNP_{it-1} + \varepsilon_{7it} \quad (4.7)$$

$$DLINEQ_{it} = \alpha_{8i} + \beta_{8i1}DLKPUB_{it} + \beta_{8i2}DLY_{it} + \beta_{8i3}DLUNP_{it} + \gamma_{8i1}LINEQ_{it-1} + \gamma_{8i2}LY_{it-1} + \gamma_{8i3}LHDI_{it-1} + \gamma_{8i4}LTRD_{it-1} + \gamma_{8i5}LTR_{it-1} + \gamma_{8i6}LUNP_{it-1} + \varepsilon_{8it} \quad (4.8)$$

$$DLINEQ_{it} = \alpha_{9i} + \beta_{9i1}DLKPRIV_{it} + \beta_{9i2}DLY_{it} + \beta_{9i3}DLUNP_{it} + \gamma_{9i1}LINEQ_{it-1} + \gamma_{9i2}LY_{it-1} + \gamma_{9i3}LHDI_{it-1} + \gamma_{9i4}LTRD_{it-1} + \gamma_{9i5}LTR_{it-1} + \gamma_{9i6}LUNP_{it-1} + \varepsilon_{9it} \quad (4.9)$$

Equations (4.7), (4.8), and (4.9) stand for the parsimonious specifications that have been reached. All specification tests were redone to ensure that all assumptions remained the same (see Table A4.1, Table A4.2, and Table A4.3 in Appendix). The results from the parsimonious versions of Model I, Model II, and Model III can be seen in Table 4.11.

Table 4.11 – PARDL estimation results – Parsimonious models

Dependent Variable: DLINEQ	Model I	Model II	Model III
Constant	0.3693***	0.3690***	0.3705***
DLK	0.0148***	-	-
DLKPUB	-	0.0118***	-
DLKPRIV	-	-	0.0168***
DLY	-0.0113***	-0.0132***	-0.0102***
DLUNP	0.0096***	0.0098***	0.0095***
LINEQ (-1)	-0.0877***	-0.0870***	-0.0882***
LY (-1)	-0.0021*	-0.0023**	-0.0020*
LHDI (-1)	-0.0739***	-0.0730***	-0.0736***
LTRD (-1)	-0.0091***	-0.0093***	-0.0090***
LTR (-1)	-0.0126***	-0.0123***	-0.0128***
LUNP (-1)	0.0102***	0.0099***	0.0103***
Diagnostic statistics			
N	386	386	386
R^2	0.3542	0.3510	0.3572
F	F(9, 21) = 42.80***	F(9, 21) = 39.12***	F(9, 21) = 46.77***

Notes: ***, **, and * denote statistical significance at 1%, 5%, and 10% level, respectively; the Stata command *xtscc* was used to estimate the models.

Looking at the outcomes from Table 4.9 and Table 4.11, the results from the non-parsimonious and parsimonious specifications are very similar. There are only some minor differences in the coefficient values and the statistical significances of some of the variables.

Starting with the analysis of Model I, it can be seen that, in the short-run, the variables total capital stock (K), gross domestic product (Y), and unemployment rate (UNP) all appear to have a statistically significant effect on income inequality (INEQ). However, while the gross domestic product (Y) seems to contribute to reducing the LAC countries income inequality (INEQ) in the short-run, the variables capital stock (K) and unemployment rate (UNP) seem to present an inverse effect. Both variables show signals of having an enhancing effect on these countries income inequality (INEQ). Additionally, the main driver of income inequality (INEQ) in the short-run seems to be, indeed, the variable total capital stock (K).

In the remaining models, Model II and Model III, when capital stock is decomposed in its public and private dimensions (KPUB and KPRIV, respectively), the results seem to point to similar inferences. However, comparing both models, the enhancing effect of private capital stock (KPRIV) on income inequality (INEQ) seems to be higher than the one from public capital stock (KPUB).

As in the case of Table 4.9, the long-run elasticities are not displayed in Table 4.11. In order to move to the long-run analysis, they must once again be calculated. Table 4.12

displays the long-run elasticities, the short-run impacts, and the adjustment speed of the parsimonious specifications of Model I, Model II, and Model III.

Table 4.12 – Elasticities, short-run impacts, and speed of adjustment – Parsimonious models

Dependent Variable: DLINEQ	Model I	Model II	Model III
Short-run impacts			
DLK	0.0148***	-	-
DLKPUB	-	0.0118***	-
DLKPRIV	-	-	0.0168***
DLY	-0.0113***	-0.0132***	-0.0102***
DLUNP	0.0096***	0.0098***	0.0095***
Long-run (computed) elasticities			
LY (-1)	-0.0241**	-0.0270**	-0.0231**
LHDI (-1)	-0.8423***	-0.8397***	-0.8350***
LTRD (-1)	-0.1039***	-0.1067***	-0.1020***
LTR (-1)	-0.1436***	-0.1416***	-0.1448***
LUNP (-1)	0.1158***	0.1141***	0.1165***
Speed of adjustment			
ECM	-0.0877***	-0.0870***	-0.0882***

Notes: ***, and ** denote statistical significance at 1% and 5% level, respectively; the ECM denotes the coefficient of the variable LINEQ lagged once.

Looking at the results from the three models in Table 4.12, the gross domestic product (Y), the human development index (HDI), trade (TRD), and the tax revenue (TR), all seem to contribute to the decrease in these countries income inequality (INEQ) in the long-run. Among these variables, the human development index (HDI) seems to be the one that contributes the most to reduce income inequality (INEQ). In contrast, the unemployment rate (UNP) is the only one of the included variables that seem to promote income inequality (INEQ) in the long-run. Finally, although the unemployment rate (UNP) has a similar effect in the short- and long-run, the magnitude of its effect seems to be larger in the long-run.

One aspect that should also be emphasized is the absence of a statistically significant effect from (total) capital stock (K) on income inequality (INEQ) in the long-run. This outcome also occurs in Model II and Model III cases, with the public (KPUB) and private (KPRIV) dimensions of capital stock. Because of this reason, and as it was already stressed, these variables were not included in the parsimonious specifications.

Regarding the ECM terms of the three models, they are all negative and statistically significant at the 1% level. This can be a sign of the presence of cointegration/long-memory in the variables. Moreover, the magnitude of the ECM coefficients indicates that the speed at which the dependent variable returns to equilibrium after variations in the independent variables is relatively low/moderate. This means that when the models are faced with shocks, they require a considerable amount of time to return to equilibrium.

Due to the statistical significance of the ECM terms, it can also be considered that when a parameter is statistically significant, it is identical to testing for Granger causality (Jouini, 2015).

When researchers analyse regions as the LAC, they should not ignore the possible existence of several political and economic shocks which could influence the results from their estimations and lead to inaccurate conclusions. Given this presumption, a set of dummy variables were added to the three models to control for the shocks that may have affected these countries' income inequality levels. In this way, it is possible to test the robustness of the results which were previously achieved.

The method consists of, first, identifying the events that may have produced peaks/breaks of large magnitude in the income inequality of these sample of countries. Second, perform a residual's analysis in order to confirm the existence of such shocks. Finally, incorporate dummies in the regressions to correct the shocks (peaks/breaks) which were identified (e.g. Santiago et al., 2020; Fuinhas et al., 2017).

The dummies which were added were the following: BRA2016; GTM2013; GTM2014; PRY2004; URY2010; URY2011; URY2012. Regarding their description, it can be said that:

- BRA2016: Corrects the peak observed in Brazil in 2016. This peak could be explained by the effects of the Brazilian crisis, which started in mid-2014, with the deceleration of the Chinese economy and the fall in commodity prices and culminated with the impeachment of Dilma Rousseff in 2016. This unfavourable situation generated a set of adverse effects on the Brazilian macroeconomic stability, namely on income inequality, with the rise in unemployment and the decline in real wages.

- GTM2013 and GTM2014: Correct the breaks observed in Guatemala in 2013 and 2014, respectively. These breaks could be probably linked with the tax reforms adopted in 2012 by the Guatemalan government in order to improve its revenues and its public social spending, and which increased the progressivity of the country tax system.

- PRY2004: Corrects the break observed in Paraguay in 2004. This break could be possibly connected with the fact that, after some years of decline and stagnation, Paraguay registered a recovery in 2003 and 2004 (in part due to high commodity prices). At the same time, in 2003, the Paraguayan government also introduced

a set of welfare programs that, combined with the country's economic recuperation, could have contributed to influence, in a great deal, its income inequality levels.

- URY2010, URY2011, and URY2012: Correct the breaks observed in Uruguay in 2010, 2011, and 2012. These breaks could be linked with the election of José Mujica as President of Uruguay in 2010. Although income inequality has begun to fall around 2007 when José Mujica rose to power, one of his biggest flags was the fight against inequalities and wealth concentration. The measures that were taken under his presidency, as the rise in the minimum wage and the expansion of social spending, have surely affected Uruguay's income gap.

The results of the parsimonious specifications of Model I, Model II, and Model III with the correction of shocks are shown in Table 4.13.

Table 4.13 – PARDL estimation results – Parsimonious models corrected for shocks

Dependent Variable: DLINEQ	Model I	Model II	Model III
Constant	0.3506***	0.3503***	0.3520***
DLK	0.0126***	-	-
DLKPUB	-	0.0094**	-
DLKPRIV	-	-	0.0145***
DLY	-0.0107***	-0.0126***	-0.0097***
DLUNP	0.0070***	0.0071***	0.0069**
LINEQ (-1)	-0.0777***	-0.0771***	-0.0783***
LY (-1)	-0.0028**	-0.0030**	-0.0027**
LHDI (-1)	-0.0617***	-0.0609***	-0.0616***
LTRD (-1)	-0.0088***	-0.0090***	-0.0087***
LTR (-1)	-0.0147***	-0.0144***	-0.0149***
LUNP (-1)	0.0070***	0.0067***	0.0071***
BRA2016	0.0261***	0.0261***	0.0260***
GTM2013	-0.0215***	-0.0214***	-0.0216***
GTM2014	-0.0210***	-0.0209***	-0.0210***
PRY2004	-0.0207***	-0.0206***	-0.0207***
URY2010	-0.0260***	-0.0265***	-0.0257***
URY2011	-0.0305***	-0.0306***	-0.0303***
URY2012	-0.0344***	-0.0343***	-0.0344***
Diagnostic statistics			
N	386	386	386
R^2	0.4874	0.4845	0.4898
F	F(16, 21) = 470.25***	F(16, 21) = 490.76***	F(16, 21) = 473.34***

Notes: *** and ** denote statistical significance at 1% and 5% level, respectively; the Stata command *xtscc* was used to estimate the models.

Looking at the results from Table 4.13, it can be seen that in the short-run, with the inclusion of dummies, the results remained similar to the ones from the models without the correction of shocks (Table 4.11). Again, there are only a few differences in the coefficients (which seem to be smaller). Thus, the previous short-run inferences remain identical: the gross domestic product (Y) seems to contribute to reducing income

inequality (INEQ); the total capital stock (K) and unemployment rate (UNP) seem to contribute to enhancing income inequality (INEQ).

Private capital stock (KPRIV) and public capital stock (KPUB) also continue to show an enhancing effect on income inequality (INEQ), with a larger magnitude in the case of the private capital stock (KPRIV). Regarding the dummy variables, it seems that their inclusion was entirely suitable, given that the coefficients from all the dummy variables are all statistically significant at a 1% level (Table 4.13).

Again, as in the previous cases, the long-run elasticities had to be calculated. Table 4.14 presents the long-run elasticities, the short-run impacts, and the adjustment speed of the three models with the correction of shocks.

Table 4.14 – Elasticities, short-run impacts, and speed of adjustment– Parsimonious models corrected for shocks

Dependent Variable: DLINEQ	Model I	Model II	Model III
Short-run impacts			
DLK	0.0126***	-	-
DLKPUB	-	0.0094**	-
DLKPRIV	-	-	0.0145***
DLY	-0.0107***	-0.0126***	-0.0097***
DLUNP	0.0070***	0.0071***	0.0069**
Long-run (computed) elasticities			
LY (-1)	-0.0358**	-0.0390***	-0.0347**
LHDI (-1)	-0.7940***	-0.7899***	-0.7868***
LTRD (-1)	-0.1137***	-0.1169***	-0.1115***
LTR (-1)	-0.1891***	-0.1865***	-0.1901***
LUNP (-1)	0.0896***	0.0875***	0.0906***
Speed of adjustment			
ECM	-0.0777***	-0.0771***	-0.0783***

Notes: ***, and ** denote statistical significance at 1% and 5% level, respectively; the ECM denotes the coefficient of the variable LINEQ lagged once.

As in the short-run, the long-run outcomes stayed similar to those without the correction of shocks, with some minor changes in the values of the coefficients and the statistical significance of the effects. As an example, the statistical significance of the gross domestic product (Y) effect in Model II went from 5% to 1% level.

In general, the signals of the coefficients remained the same. The gross domestic product (Y), the human development index (HDI), trade (TRD), and the tax revenue (TR) still show to be able to decrease income inequality (INEQ), and the unemployment rate (UNP) still appears to promote income inequality (INEQ).

In addition, the ECM terms of the three models continue to be all negative and statistically significant at the 1% level. However, they all suffered a slight decrease in their

magnitude, which means that with the inclusion of dummies, the adjustment speed of the three models becomes somewhat slower.

Overall, it can be concluded that, although the inclusion of dummies has proved to be adequate, the results do not differ much when the models are corrected for shocks. This means that the outcomes and inferences from the first set of models, i.e. without the inclusion of the dummy variables, remain accurate.

Discussing the main results of the analysis, it seems that economic growth can be a powerful tool to reduce income inequality. In fact, the variable gross domestic product (Y) showed to have had a depressing effect on income inequality (INEQ) both in the short-run and long-run in all three models. This result suggests that the economic performance of these countries can, indeed, influence their income inequality levels.

More precisely, it suggests that the LAC countries governments are trying to develop/promote inclusive growth policies so that the positive effects of their economic performance can benefit all the population layers (with the combination of growth-enhancing policies with measures focused on the promotion of a more equitable society). These governments should continue to follow this trend in order to grant that the gains from their growth will not only be channelled to the highest strata of the population. Moreover, this result seems to be in line with the ones from past studies, for example, the one from Tsounta and Osueke (2014), who used a sample similar to the one from this analysis.

Conversely to gross domestic product (Y), the unemployment rate (UNP) showed to have had an augmenting effect on these countries income inequality (INEQ) levels, both in the short- and long-run. This result indicates that increased unemployment contributes to enlarge the income gap, with a persistent effect that extends over time.

This means that in order to tackle income inequality, LAC governments should concentrate some effort on the fight against unemployment. There is the need to develop, for example, policies to encourage job creation and measures that grant enlarged job opportunities for all. Overall, this outcome indicates that fighting against unemployment is also fighting against income inequality. As in the previous case, this result is also accordant with past literature findings (e.g. Hacibedel et al., 2019).

Regarding the variables which have only demonstrated statistically significant effects in the long-run, one can start with the human development index (HDI). The fact that it showed to be able to reduce income inequality (INEQ) traduces the general view that

policies aimed at the improvement of the standard of living of populations (e.g. the government investment in education and health) contribute in a great deal to a more equal society (e.g. Martínez-Vázquez et al., 2012). This conclusion suggests that the LAC countries governments should continue to invest in the well-being of their populations, especially of the lower-income groups, in order to achieve greater social cohesion and a more equal income distribution.

In the same line, the tax revenue (TR) also showed to be able to reduce income inequality (INEQ). This probably means that taxation has a redistributive effect in these countries, contributing to alleviating their income gap and that the region's governments should continue to support their social welfare programs with their tax revenues.

However, as most of these countries have low levels of tax revenues (see, e.g. Martorano, 2018), it could be essential to improve the tax schemes (e.g. with more progressive taxation) in order to obtain higher revenues. This will possibly help to support their public expenditure policies, namely the ones focused on income inequality reduction. Finally, this result also seems to be validated by some of the previous literature (e.g. Martorano, 2018; Balseven and Tugcu, 2017).

Now, concerning the effects of trade (TRD) on income inequality (INEQ), it can be seen that, while the literature has found mixed results, the outcomes from this analysis seem to support the view that trade has a reducing effect on income inequality (e.g. Cerdeiro and Komaromi, 2017). Although the LAC has indeed seen their income inequality levels increase in the '80s and '90s, which coincided with the increasing integration of the region in the global economy, this trend was reversed with the beginning of the new millennium (see Székely and Sámano-Robles (2014)).

The major drivers behind the inversion were the stabilisation of the trade liberalisation process in the region and the policy reforms developed to promote growth and control inequality (Cornia, 2011). In the end, this result suggests that these countries should continue their integration process, given the positive effects that this can have on their economic output (e.g. Santiago et al., 2020), at the same time as they continue to develop policies aimed at extending the gains from trade to the general population.

Finally, answering the central question, it can be seen that the effects from total capital stock (K), public capital stock (KPUB), and private capital stock (KPRIV) on income inequality (INEQ) were all positive and statistically significant. In other words, all these variables seem to have contributed to the deterioration of the income distribution in

these countries. Indeed, all of them presented an enhancing effect on the LAC countries income inequality (INEQ) levels in the short-run.

However, it should be mentioned that in the long-run, none of these variables showed to have a statistically significant effect on income inequality (INEQ). Moreover, another fact which should also be mentioned is that the effect of private capital stock (KPRIV) on income inequality (INEQ) always seemed to be higher than the one from public capital stock (KPUB).

These findings reveal some worrying aspects from the physical capital investments in these countries. First, it seems that the public and private investment in physical capital (e.g. roads, railways, bridges, schools, hospitals, sanitation and water systems, telecommunications and energy systems, public transportation, among others) is being made in the already rich/wealthiest areas, where there is evidence of a particular economic dynamism, rather than being channelled to the poorest/undeveloped areas (see, e.g. Lopez, 2003). In fact, this seems to be the strongest justification for the enhancing effect of all capital stocks on income inequality (INEQ) in the short-run.

Indeed, some authors already acknowledged this issue in their investigations and who already warned about the necessity of the LAC to increase the investment in the rural and more undeveloped areas of the region. As an example, Brushett and John-Abraham (2006) state that the infrastructure coverage in the rural areas of the LAC is characteristically low, with the provision of infrastructure in these areas being far behind that of the urban areas.

Moreover, according to Fay et al. (2017), the increased investment in rural communities and their connection with the rest of the territory is essential to grant the inclusive development of the LAC region. Also, following Pérez (2020), in addition to the necessity to increase infrastructure investment, the LAC should upgrade the selection and management of these same investments in order to grant that they will be long-term planned and territorially balanced. In his view, this is essential so that the region could adapt to the economic, social, and environmental changes and concerns that will arise with the region's development.

With respect to the effect of the private capital stock (KPRIV) on income inequality (INEQ), one should also account for the fact that the private interest is majorly driven by profit. Therefore, it is natural that they invest in areas where higher profits are

guaranteed (generally in the most developed areas) in the absence of government incentives.

In addition to this, it must also be considered the possible barriers that the private control of, for example, energy, infrastructure and transport services, can generate to the poorest groups of the population. Usually, private enterprises charge higher prices for their services compared to public enterprises, which could reduce the access and affordability of these services by the most disadvantaged strata of the population. These additional assumptions can probably help to explain why the magnitude of the effect of private capital (KPRIV) on income inequality (INEQ) is greater than the one from the public capital (KPUB).

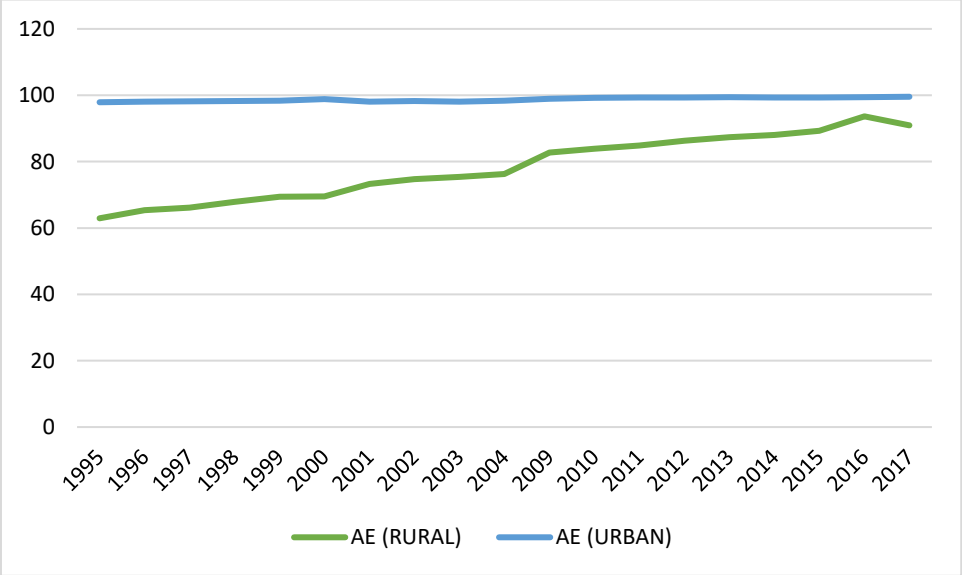
Some considerable attention should also be paid to the lack of a statistically significant effect from the total capital stock (K), the public capital stock (KPUB), and the private capital stock (KPRIV) on income inequality (INEQ) in the long-run. This result is probably associated with the fact that over time, governments try to correct the harmful short-run effect with increased investment in the undeveloped/rural areas (and/or with the creation of incentives to the private sector to invest in these same areas).

However, even with the suppression of the negative effect, it seems that the investment levels and the investment strategies which are followed are not yet capable of inducing capital stock (K, KPUB, KPRIV) on having a negative and statistically significant effect (i.e. a reducing effect) on income inequality (INEQ) in the long-run. In other words, it seems that although the effort to develop better rural infrastructure in LAC (as it was recognized by the International Fund for Agricultural Development (IFAD, 2016)), the investments which were made have not yet been able to produce a significant effect on the fight against income inequality.

Looking at some of the data available in the "*World Development Indicators*" Database of the World Bank (Figure 4.1), it is seen that there are signs of progress in some fields. In 1995 only 62.9% of the rural population of the LAC had access to electricity, which contrasts with the value from 2017, where this percentage achieved the 91%. This seems to show that there was an effort to increase the electricity coverage (and its necessary infrastructure) in the poorest/undeveloped areas, which in the end can help to mitigate income inequality.

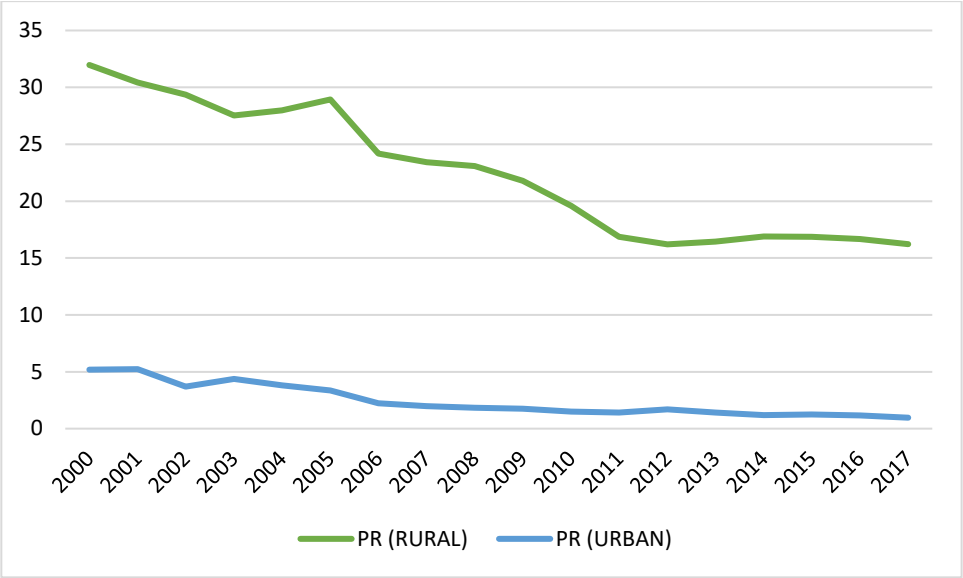
However, the investment still seems to be insufficient (or is it just channelled into solving some specific problems (e.g. lack of electricity coverage)), and it is not yet capable of

producing the desired cohesion. In fact, some economic indicators continue to point the rural areas of this region as the areas where people need to struggle more to get out of poverty or, in other words, where the risk of falling into poverty is huge. According to the "LAC Equity Lab" and the World Bank's $1.90-a-day (2011 purchasing power parity prices) International Poverty Line for the LAC aggregate, it can be seen that while in the region's rural areas, the poverty rate in 2017 was 16,2%, in urban areas this same rate was only around the 1% (Figure 4.2).



Notes: This graph was created by the author recurring to "Access to electricity, rural (% of rural population)" and "Access to electricity, urban (% of urban population)" data for the LAC aggregate from the "World Development Indicators" database of the World Bank. The "green line" represents the percentage of rural population with access to electricity (AE (RURAL)), whereas the "blue line" represents the percentage of urban population with access to electricity (AE (URBAN)).

Figure 4.1 – Access to Electricity in LAC (Rural and Urban) (1995-2017)



Notes: This graph was created by the author recurring to poverty rate data for the LAC aggregate from the LAC Equity Lab. The "green line" represents the percentage of people living on less than $1.90 a day (2011 purchasing power parity prices) in rural areas (PR (RURAL)), whereas the "blue line" represents the percentage of people living on less than $1.90 a day (2011 purchasing power parity prices) in urban areas (PR (URBAN)).

Figure 4.2 – Poverty Rate in LAC (Rural and Urban) (2000-2017)

Finally, it should be mentioned that all these results held either in the non-parsimonious as in the parsimonious models, as well as when dummy variables were included in the three models to correct for the effects of the outliers that were found. In the following section (Section 4.5), the conclusions and policy implications that can be drawn from the outcomes of the analysis will be presented.

4.5 Conclusions and Policy Implications

In this chapter, there was an effort to uncover the effects that the LAC capital stock has had on the income inequality levels of a group of 18 regional countries between 1995 and 2017. In order to accomplish the goals of the analysis, three models were constructed: (1) Model I with capital stock (K) as the interest variable: (2) Model II with the general government capital stock/public capital stock (KPUB) as the interest variable; and (3) Model III with private capital stock (KPRIV) as the interest variable.

The econometric analysis was based on the use of the PARDL model in the form of a UECM. The choice of such a methodology was primarily related to the fact that it allows identifying the short- and long-run impacts of the explanatory variables on the dependent variable, being robust when there are signals of endogeneity.

Since was found evidence on the presence of cross-sectional dependence, heteroskedasticity, and autocorrelation in all three models, the DK estimator with FE was used to estimate these same models. The reason behind this choice was the fact that this estimator produces standard errors robust to the disturbances being cross-sectionally dependent, heteroskedastic, and autocorrelated.

The results from Model I, with the non-parsimonious and parsimonious specification, indicate that, in the short-run, the gross domestic product seems to contribute to reducing these countries income inequality, while the total capital stock and unemployment rate seem to raise their income inequality levels. In Model II and Model III, when the capital stock was decomposed in its public and private dimensions, the short-run results seem to be similar to the ones from Model I, but this time with both types of capital presenting an enhancing effect on income inequality. Moreover, the results from Model II and Model III also hold with the non-parsimonious and parsimonious specifications.

Regarding the long-run analysis, from the results of the three models, it is seen that the gross domestic product, the human development index, trade, and tax revenue all contribute to the decrease of these countries income inequality in the long-run. Simultaneously, the unemployment rate seems to be the only variable (among the included variables) that seems to promote it.

Moreover, it should be mentioned that, in the long-run, none of the capital stock variables (total, public and private) showed a statistically significant effect on income inequality. Once again, the outcomes and conclusions were similar either in the non-parsimonious and parsimonious specifications of the models. Finally, when the three models were corrected for the presence of shocks/outliers, the conclusions also remained identical, which raises the confidence in the robustness of the results.

According to these outcomes, the LAC governments should rethink their physical capital investment strategies. In fact, it seems that the investment was primarily made in the areas where there was already a certain level of development/richness. If no changes are made, and they continue to ignore the areas where physical capital investments are truly necessary, i.e. the poorest/undeveloped areas, these countries' cohesion will continue to be threatened.

In this sense, the region’s governments should firstly improve the management and the selection criteria of the public investments. Indeed, there is the need to channelise a

significant part of them to the development of the poorest/rural areas, making it possible to link them to the richer areas where there is a more thriving economic activity. Ultimately, this will probably allow an increased income convergence.

Moreover, it can also be important that these governments create incentives to that the private initiatives also invest in these areas, as otherwise, this is unlikely to happen. This can be especially significant in the case of countries that face a low degree of economic slack and, for that reason, have more difficulty in investing in public capital.

An alternative can be the development of public-private partnership (PPP) schemes. Still, the private initiative and cooperative arrangements (as PPP's) in areas as, for example, infrastructure provision, should be intensively examined/discussed by public entities. This because there is the need to guarantee that the legitimate public purpose will be reached and that the low-income layers of the population will not be neglected.

Lastly, even though the nefarious effect from capital stock on income inequality seems to disappear in the long-run, probably due to the efforts made to counter this situation, the investment seems to be still insufficient to produce the desired reducing effect on income inequality. Thus, there is still the need to increase the LAC physical capital investment levels, especially in areas where physical capital is scarce. As Pérez (2020, p. 14) stressed, "*Infrastructure planning with a long-term and territorially balanced perspective*" continues to be a necessity in the LAC.

The increased investment should be accompanied by the upgrade in the quality of the LAC physical capital investment projects, either in their implementation as well as in their preparation and structuration. In addition, to allow the public investment to be more efficient, this can also increase the likelihood of attracting private partners to help finance physical capital projects in cases of need.

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Appendix

Table A4.1 – Hausman tests (FE vs RE) – Parsimonious models

	Model I	Model II	Model III
	FE vs. RE	FE vs. RE	FE vs. RE
Hausman test	Chi2(9) = 97.55***	Chi2(9) = 96.54***	Chi2(9) = 97.36***
Hausman test (with *sigmamore*)	Chi2(9) = 86.50***	Chi2(9) = 88.82***	Chi2(9) = 85.24***
Hausman test (with *sigmaless*)	Chi2(9) = 109.68***	Chi2(9) = 113.52***	Chi2(9) = 107.60***

Notes: *** denotes significance at 1% level; H0: difference in coefficients not systematic/RE is preferable; the Stata command *hausman* (with and without the *sigmamore* and *sigmaless* options) was used to compute this test.

Table A4.2 – Hausman tests (MG vs PMG vs Pooled) – Parsimonious models

	Model I	Model II	Model III
	MG vs. PMG	MG vs. PMG	MG vs. PMG
Hausman test	Chi2(9) = -3.51	Chi2(9) = -3.66	Chi2(9) = 3.10
	PMG vs Pooled	PMG vs. Pooled	PMG vs. Pooled
	Chi2(9) = 2.38	Chi2(9) = 3.01	Chi2(9) = 3.35
	MG vs Pooled	MG vs. Pooled	MG vs. Pooled
	Chi2(9) = 20.49**	Chi2(9) = 35.59***	Chi2(9) = 14.91

Notes: *** denotes statistically significant at 1%; H0: difference in coefficients not systematic; to compute this test, the Stata commands *xtdcce2* and h*ausman* were used.

Table A4.3 – Specification tests – Parsimonious models

	Model I	Model II	Model III
	Statistics	Statistics	Statistics
Modified Wald test	145.37***	144.97***	145.36***
Pesaran's test	2.863***	2.981***	2.798***
Frees' test	0.871***	0.824***	0.866***
Friedman's test	29.982**	30.856**	29.407**
Wooldridge test	9.483***	19.484***	19.484***

Notes: ** and *** denote statistical significance at 5% and 1% level, respectively; H0 of Modified Wald test: sigma(i)^2= sigma^2 for all I; H0 of Pesaran's, Frees', and Friedman's: residuals are not correlated; H0 of Wooldridge test: no first-order autocorrelation; to compute these tests, the Stata commands *xttest3*, *xtcsd*, *xtserial* were used, respectively.

Chapter 5

An analysis of the energy intensity of Latin American and Caribbean countries: Empirical evidence on the role of public and private capital stock

In this chapter, the role of public and private capital stock in the energy intensity of 21 Latin American and Caribbean (LAC) countries was analysed from 1970 to 2014. The empirical analysis of this chapter was based on three methodologies, namely: 1) the panel autoregressive distributed lag (PARDL) model; 2) the log t regression test method and the club clustering algorithm; and 3) the ordered-logit regression model. The results from the analysis indicated that, although the decreasing trend of LAC energy intensity, the public and private capital stocks did not contribute to this trend, given that they seem to have had an enhancing effect on the long-run LAC energy intensity. It was also identified the existence of four convergence in terms of energy intensity, with different transition paths and different levels. By the ordered logit estimation, it was found that neither the public nor private capital stocks are determinant in club convergence/formation. The overall conclusion is that LAC governments should increase investment in more energy-efficient equipment and infrastructure. This should be done at the same time as they create or improve the laws and the regulatory framework regarding energy efficiency and create incentives to allow private physical capital to follow the same tendency.

5.1 Introduction

All over the world, governments and institutions are making additional efforts in order to enable countries to reach a sustainable development path. The increased worries related to the world's environmental degradation are actively contributing to this trend, as researchers increasingly seek to address problems related to this theme.

One question that has been receiving growing research interest in the environmental and energy economics fields is how the countries can improve their energy use. Although one knows that countries need to use energy to support their production, the present environmental worries, together with countries' energy security concerns, make the

demand for energy efficiency a crucial subject of analysis. In fact, this topic has been gaining more and more importance in worldwide political agendas.

Looking deeper into the case of the Latin America and Caribbean (LAC) region and following the report called "*Lights on? Energy Needs in Latin America and the Caribbean to 2040*" (Balza et al., 2016), the regional energy consumption has significantly increased in the last four decades. Indeed, the LAC energy consumption has more than tripled since the 1970s, accompanying the growth strategies of this region.

The "*Washington Consensus*" and the "*Brady Plan*" are some examples of the macroeconomic adjustment programmes that have been put in place in the LAC region in order to increase its levels of liberalisation and openness, and subsequently, boost its economic growth (Koengkan et al., 2019). Moreover, the so-called "*commodity boom*" is also frequently pointed out to explain the accelerated increase in the regional economic output (Carneiro, 2012).

Despite the fast growth of renewable energy in the LAC region (Flavin et al., 2014), most of its countries continue to be fossil-fuel dependent, either as producers or consumers (Fuinhas et al., 2017). This means that their productive structure is still very dependent on non-renewable energy consumption, which leads to significant increases in their CO2 emissions (Al-mulali et al., 2015) and to an increase in their propensity to be affected by fossil-fuel price fluctuations and further external shocks (Jacobs et al., 2013).

All these features seem to indicate that LAC governments should continue to improve their energy structure, alongside their energy use, in order to be able to cope with the expectations related to their future regional energy demand and to surpass their concerns regarding climate change. Following this idea, there are a vast number of relationships that could be investigated in order to help LAC policymakers on the buildout of sustainable development strategies for this region.

One relationship which is very underexplored is that which capital stock has with energy consumption. More precisely, the relationship that this variable has with concepts such as energy efficiency or energy intensity. This is strange because capital and energy are intrinsically related. In fact, buildings, vehicles, machines, tools (and other types of physical capital) require energy to produce the goods and services that populations need. Due to this connection, it is wise to think that the analysis of the effects from the LAC public and private capital stocks on the regional energy intensity could be further explored.

Energy intensity is a measure that represents a country's capacity to convert energy into monetary output and is considered as one of the various proxies that can be used to evaluate a country's energy efficiency (Martínez et al., 2019). The analysis of this relationship can be used to perceive how this region's physical capital has contributed to the evolution of LAC in terms of energy efficiency.

To increase interest in analysing this relationship, it could also be referred that the LAC region suffers from an identified "*infrastructure gap*" that could be (and has been) harmful for their economic sustainability and development (Perrotti, 2011). This implies that the region will probably need to raise investment in its physical capital soon.

Overall, the main objective of this chapter is to understand if new and more energy-efficient physical capital investments are needed in the LAC region. To achieve such a goal, the effects of LAC capital stock on the region's energy intensity will be assessed through the use of a panel autoregressive distributed lag (PARDL) model. In addition, the convergence of LAC countries in terms of energy intensity will be explored through the division of these countries into the so-called "*convergence clubs*" (Phillips and Sul, 2007). Finally, it will also be investigated whether public and private capital stocks explain the formation of these same convergence clubs through an ordered-logit regression model.

The significance of this chapter is primarily linked to the abovementioned fact that this relationship (capital stock-energy intensity) has been very underexplored in previous literature. Additionally, the fact that different methodologies were used to investigate the role of capital stock in energy intensity can also be pointed out as another factor that increases the significance of this chapter.

Moreover, due to the problems associated with the lack of new physical capital investments in the LAC region (the previously mentioned "*infrastructure gap*") and the accentuated increase in the region's energy consumption in recent decades, it has become especially important to study this relationship in this region. This is because it is essential that the future LAC physical capital investments (already recommended by international organisations such as the International Monetary Fund (IMF)) be channelled towards the region's sustainable development.

This chapter is organised as follows: Section 5.2 presents the literature review; Section 5.3 describes the data and methodology; Section 5.4 provides both the empirical results and their discussion; Section 5.5 concludes and presents the policy implications. It is also

important to refer that Section 5.4 is divided into three sub-Sections, according to the methodologies that were used: 5.4.1 Panel Autoregressive Distributed Lag; 5.4.2 Convergence Clubs; 5.4.3 Ordered Logit.

5.2 Literature Review

Energy efficiency could be simply defined as "*using less energy to produce the same amount of services or useful output*" (Patterson, 1996, p. 377). In the past few decades, there has been an increased interest in energy efficiency studies as also in their subsequent results (Dunlop, 2019). This has happened mainly due to the growing need for public and private institutions to find solutions to overcome the problems linked with energy security and environmental degradation that have been exacerbated in many countries around the world (Lutzenhiser, 2014).

Looking at the previous literature, there is a range of energy efficiency indicators that researchers could use. One indicator which is frequently used, especially at the macro level, is the energy intensity ratio (Filipović et al., 2015). This indicator can be used to measure the energy efficiency of a given economy, being usually computed via the ratio between the country/region energy use and their respective gross domestic product (Martínez et al., 2019). The smaller the energy intensity ratio of a country/region, the lower its energy intensity.

The analysis of the energy intensity determinants can be very useful for policymakers because it can help them in designing energy policies aimed at lowering energy intensity (and increasing energy efficiency). Due to this, it is natural that this type of analysis has been carried out for several countries and regions with different panel data (and cross-sectional data) estimation techniques (e.g. Samargandi, 2019; Filipović et al., 2015; Jimenez and Mercado, 2014).

As examples, we can cite the study of Filipović et al. (2015) for the European Union (EU) or the one from Samargandi (2019) centred on the Organisation of the Petroleum Exporting Countries (OPEC). In the first, it was found that energy prices and gross domestic product contributed to the energy intensity reduction, whereas energy consumption contributed to the energy intensity increase. In the second, it was found that trade openness and renewable energy seem to contribute to reducing energy intensity while energy prices seem to contribute to its increase.

Regarding the sample of this chapter, we can cite the studies of Jimenez and Mercado (2014) and Balza et al. (2016). Through a decomposition analysis, Jimenez and Mercado (2014) found that factors such as per capita income, petroleum prices, fuel-energy mix, and GDP (gross domestic product) growth seem to be all core determinants of the LAC energy intensity. Following Balza et al. (2016), the decline in the LAC energy intensity for the past forty years can be mainly attributed to a possible improvement of the region's energy consumption productivity.

Apart from the previously cited determinants, one factor that should have its relationship with concepts such as energy efficiency or energy intensity further investigated is physical capital. According to Martínez et al. (2019), countries can lower their energy intensity by improving their energy sector extraction and conversion techniques, by transferring a large part of the manufacturing production to other countries or by the improvement of the efficiency of the materials used by their production system. In a similar sense, Voigt et al. (2014) also consider newer and more efficient capital equipment as an essential factor for countries to be able to decrease their energy intensity.

Moreover, following the International Energy Agency (IEA, 2018) and the Organisation for Economic Co-operation and Development (OECD, 2015), to achieve the desirable clean energy transition and the green growth and development objectives, there is the need to increase the countries' investment in energy efficiency. More properly, there is the need to invest in the improvement of the energy efficiency of energy-using equipment in households, firms and governments, and to invest in cleaner and more efficient infrastructure.

Indeed, there are several studies that have already pointed to the harmful effects that the weak state of LAC infrastructures may have on the region's development (Faruqee, 2016; Perrotti, 2011). However, as it was already explained, capital stock not only represents infrastructure (e.g., roads, bridges, buildings) but also represents other types of physical capital, such as machines and equipment.

Following Ravillard et al. (2019), although the improvements registered in overall LAC energy intensity, its industry sector still demonstrates higher energy intensity compared with other world regions. This could possibly mean that that the LAC's machinery and equipment may also need to be upgraded.

One crucial factor which affects the relationship between physical capital and energy is technological progress (or innovation). In fact, it is recognized that this factor can induce countries to invest in more energy-efficient physical capital (Murad et al., 2019; Malaczewski, 2018). However, following this notion, another possible problem arises for the LAC region. The low R&D (Research and Development) investment level and low absorptive capacity, which are usually associated with developing countries, like the ones from this region, can prevent this from happening (Koengkan, 2018, Goñi and Maloney, 2017; Burns, 2009).

Additionally, according to the United Nations (UN, 2018), countries may face some additional obstacles in promoting energy efficiency. Some examples of these obstacles are: the lack of a suitable regulatory framework; the lack of effective national institutions to promote and develop energy efficiency projects; the low international assistance; the unfavourable financial environment; the insufficient incentives from energy prices; and the low degree of awareness regarding its importance.

Also, according to the United Nations (UN, 2018), some additional factors make it more difficult for private entities to invest in the upgrade of their buildings, plants, and equipment energy efficiency. Examples of these factors are: the lack of knowledge concerning the benefits from energy efficiency projects; the lack of tax incentives and low-interest loans for energy efficiency projects; the low priority of energy efficiency for people at the core of business decision-making; the lack (or high cost) of capital; and the lack of government incentives.

As the public sector act as a legislator and as a heavy energy-consuming sector (with schools, universities, hospitals, among others, needing 24-hour load), Singh et al. (2009) state that it should set the example. In the view of Singh et al. (2009), energy efficiency investments could lead to large positive returns for governments, energy consumers and primarily for the environment. Moreover, according to Bertoldi et al. (2010), one of the major benefits of public green procurement is that, through leading by example, the public sector can stimulate the private sector on investing in energy efficiency projects.

In accordance, Ravillard et al. (2019) state that LAC energy intensity can be improved by the efforts of the region's governments and institutions. Among the various efforts which could be made, the authors stress: (1) the development of laws and regulations on energy efficiency; (2) the creation of incentives to support energy efficiency policies; (3) the creation of specific targets regarding energy efficiency for their economic sectors; and (4)

an increase in government support on these matters with, for example, the development of auction and financing schemes and providing technical assistance.

For all the above reasons, it is believed that the analysis of the impacts of the LAC capital stock on the region's energy intensity should be further investigated. This will allow perceiving the evolution of the relationship between these two variables in this region and to understand if more energy-efficient capital stock is needed in the LAC.

The reason for studying this relationship becomes even stronger in view of the scarcity of studies that directly address this issue, especially for this region (Koengkan et al., 2019). One reason that can be stressed for this lack of studies was the difficulty that the authors faced in measuring capital stock. However, this difficulty was now surpassed by the release of the "*Investment and Capital Stock Dataset*" (IMF, 2017).

Despite the previous observation, a mention should be made to the study of Ducoing et al. (2019), which analysed energy capital ratios in Europe and Latin America between 1875 and 1970. Despite being a historical analysis, its conclusions seem to be quite pertinent, given the current issues. The authors stress that energy efficiency improvements are needed to enable sustainable growth, not only because they allow the same amount of output to be produced with less energy but because they can also reduce pollutant emissions.

As was stressed in the introductory section (Section 5.1), in this chapter will also be carried out an additional analysis of the convergence of the LAC countries in terms of energy intensity. Although initially, the convergence analysis was mainly applied to test the hypothesis that the countries would eventually converge in terms of per-capita output (e.g. Pesaran, 2007a; Luginbuhl and Koopman, 2004; Barro and Sala-i-Martin, 1997), this type of analysis was rapidly extended to other subjects. As an example, some authors decide to explore the countries' convergence in terms of, for example, eco-efficiency and carbon dioxide emissions (e.g. Camarero et al., 2013; Panopoulou and Pantelidis, 2009).

The increase in studies focused on this type of analysis was enhanced mainly by the convergence analysis method proposed by Phillips and Sul (2007): the "*log t-test*", which tests the convergence hypothesis based on a nonlinear time-varying factor model. Additionally, to test the general hypothesis of convergence, this method also enables to test the existence of convergence clubs within the countries included in the sample.

As expected, the method of Phillips and Sul (2007) was also applied for testing the convergence of countries in terms of energy intensity (e.g. Yu et al., 2015). Nowadays,

the study of Yu et al. (2015) is considered as an empirical advance when compared to the previous studies that tried to examine this same type of convergence with different econometric methodologies (e.g. Le Pen and Sévi, 2010; Liddle, 2010; Markandya et al., 2006).

In addition to convergence testing and the identification of convergence clubs, there is a large number of authors who also test the determinants of the formation of these clubs (e.g. Bai et al., 2019a; Bai et al., 2019b; Bhattacharya et al., 2018; Yu et al., 2015). Usually, this analysis is conducted by employing ordered logit and ordered probit regressions, with the inclusion of variables that may affect the probability of a country belonging to a particular convergence club (e.g. Bai et al., 2019a; Bai et al., 2019b; Matysiak and Olszewski, 2019; Yu et al., 2015). Following a similar framework, in this chapter it will be tested whether capital stock (public and private) is a factor that affects club convergence in the LAC region.

After this literature review, in the next section (Section 5.3), it will be displayed the data which was collected to conduct the analysis, and it will be described the methodologies which were used to achieve the chapter's goals.

5.3 Data and Methodology

To perform this chapter analysis, annual data from 1970 to 2014 was assembled for a panel of 21 countries from the LAC region. These countries were Argentina, Barbados, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay and Venezuela.

As in the case of the previous chapters' analysis, data availability was the main criterion for choosing both the countries and the time horizon. Regarding the econometric analysis, it was developed through the use of the statistical software package Stata 15. The name, definition and sources of the raw variables are displayed in Table 5.1.

Table 5.1 – Variables description

Variable	Definition	Source
Y	Gross domestic product (in billions of constant 2011 international dollars)	Investment and Capital Stock Dataset
PEC	Primary energy consumption (in thousands of barrels of oil equivalent)	CEPALSTAT
KPUB	General government capital stock (in billions of constant 2011 international dollars)	Investment and Capital Stock Dataset
KPRIV	Private capital stock (in billions of constant 2011 international dollars)	Investment and Capital Stock Dataset
CO2PC	CO2 emissions (in metric tons per capita)	World Development Indicators
EP	Energy (commodities) prices (annual indices, 2010 = 100, real 2010 US dollars)	World Bank Commodity Price Data
P	Total population, in the total number of persons	World Development Indicators

Three different methodologies will be employed in the empirical analysis of this chapter:

- the PARDL model, in the form of an unrestricted error correction model (UECM), which will allow identifying the short- and long-run impacts of private and public capital stocks on LAC energy intensity;
- the log t regression test method and the club clustering algorithm developed by Phillips and Sul (2007), which will permit the identification of the LAC convergence clubs in terms of energy intensity;
- the ordered-logit regression model, which can be used to investigate whether public and private capital stocks are factors that drive the formation of convergence clubs.

First, it should be stressed that the use of the PARDL model to study the impacts of the LAC capital stock on the region's energy intensity was based on the facts that this model:

- allows the decomposition of the total effects of the variables into their short- and long-run components;
- deals properly with cointegration;
- is robust with the variables being endogenous;
- allows the inclusion of I(0), I(1), and fractionally integrated variables in the same estimation.

The dependent variable will be energy intensity (EI), which was achieved through the formula represented in Equation (5.1):

$$EI_{it} = \frac{PEC_{it}}{Y_{it}}, \quad (5.1)$$

where "PEC" is the primary energy consumption (in thousands of barrels of oil equivalent) of the country *i* in period *t*, and "Y" is the gross domestic product (in billions of constant 2011 international dollars) of the country *i* in period *t*. The smaller this ratio, the lower the energy intensity (Hatzigeorgiou et al., 2011; Cornillie and Fankhauser, 2004). The variable PEC was retrieved from the CEPALSTAT, whereas Y was retrieved from the "*Investment and Capital Stock Dataset*" released by the IMF (2017).

The interest variables of the PARDL will be the general government capital stock (KPUB), and the private capital stock (KPRIV). The variable KPUB was transformed in the percentage of the GDP through the ratio between the general government capital stock, in billions of constant 2011 international dollars, and the gross domestic product, in billions of constant 2011 international dollar, multiplied by one hundred. The variable KPRIV was also transformed in the percentage of the GDP in a similar way as KPUB. However, in the case of KPRIV, it was used the private capital stock, in billions of constant 2011 international dollars, instead of the general government capital stock.

The control variables will be the gross domestic product per capita (YPC), in billions of constant 2011 international dollars, the CO2 emissions in metric tons per capita (CO2PC), and the energy (commodities) prices (EP), annual indices (2011 = 100). The variable YPC was achieved through the division of "Y" by the total population (P), whereas the base year of EP was changed from 2010 to 2011 through the division of all index values by the 2011 value.

The variables KPUB and KPRIV were collected from the "*Investment and Capital Stock Dataset*" (IMF, 2017), similarly to Y, whereas CO2PC and P were collected from the "*World Development Indicators*" of the World Bank. Finally, EP was collected from the "*World Bank Commodity Price Data*", also known as "*The Pink Sheet*".

Finally, before proceeding, it is important to refer that the control variables that were included in the PARDL model were chosen based on the fact that they have already been demonstrated (theoretically and empirically) to influence a country's energy consumption patterns and/or their energy intensity/efficiency levels (e.g. Deichmann et al., 2019; Samargandi, 2019; Sineviciene et al., 2017; Hatzigeorgiou et al., 2011).

Moreover, as was previously stressed, the data availability also influenced the choice of such variables. The specification of the PARDL model is displayed in Equation (5.2), already parametrised to obtain the dynamic relations between the variables:

$$\begin{aligned} DLEI_{it} =& \alpha_i + \delta_{1i} TREND_t + \beta_{1i} DLKPUB_{it} + \beta_{2i} DLKPRIV_{it} + \beta_{3i} DLYPC_{it} + \\ & \beta_{4i} DLCO2PC_{it} + \beta_{5i} DLEP_{it} + \gamma_{1i} LEI_{it-1} + \gamma_{2i} LKPUB_{it-1} + \gamma_{3i} LKPRIV_{it-1} + \\ & \gamma_{4i} LYPC_{it-1} + \gamma_{5i} LCO2PC_{it-1} + \gamma_{6i} LEP_{it-1} + \varepsilon_{it} \end{aligned} \quad (5.2)$$

where α_i denotes the country-specific intercept (or fixed effects), δ_{ki}, β_{ki} and γ_{ki} denote the estimated parameters and the ε_{it} represents the error term. Additionally, it should be mention that the variables in Equation (5.2) are represented in natural logarithms and first differences, with the prefixes "L" and "D" denoting natural logarithms and first differences, respectively.

Furthermore, it is important to stress that the variable LEI, lagged once, represents the error correction mechanism (ECM) term, which characterises the speed of adjustment of the model. If its coefficient is negative and highly statistically significant, it supports the presence of cointegration/long-memory.

The second methodology which will be used is the log t-test proposed by Phillips and Sul (2007), which will allow testing the null hypothesis of convergence. If the null hypothesis is not rejected, then the entire sample tends to converge. If it is rejected, there is the possibility of identifying various convergence clubs (i.e. convergence subgroups).

The clubs can be identified through the clustering algorithm method originally proposed by Phillips and Sul (2007) and which was later modified by Schnurbus et al. (2017). For a detailed explanation of the steps and mathematical expressions from the log t-test and clustering algorithm methods, see Phillips and Sul (2007) and Schnurbus et al. (2017) (see also "Notes on the log t-test and the clustering algorithm" in Appendix B).

After this approach, if the existence of convergence clubs is confirmed, the formation of these clubs can be explored through the investigation of possible influencing factors. Following the previous literature (e.g. Bai et al., 2019a; Yu et al., 2015), in this analysis, it was used an ordered-logit regression model to this end. The model is described by Equation (5.3):

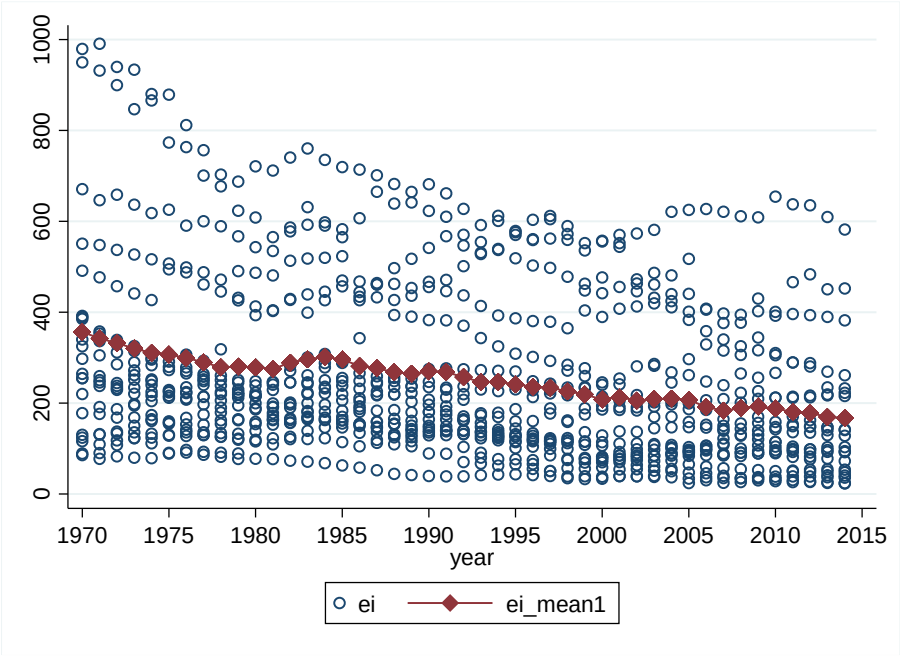
$$\begin{aligned} & y_i^* = X'_i \beta + \varepsilon_i \\ & y_i = j, \text{ if } \alpha_{j-1} \leq y'_i \leq \alpha_j, j = 1, 2, \dots, J, \end{aligned} \quad (5.3)$$

where y is the ordinal response variable denoting the club to which a determined country belongs, y^* is the latent variable that indicates a country's individual steady-state energy intensity level, X' is the vector of independent variables, β denotes the vector of regression coefficients, ε_i represents the disturbance term, the 'α's are unknown cut-points (also known as transition (threshold) parameters) in the distribution of y^* which will be estimated assuming $\alpha_0 = -\infty$ and $\alpha_j = \infty$, and J is the number of clubs.

Essentially, the latent variable y^* represents the tendency of a country to belong to one of the clubs, while the transition parameters α_j separate the clubs. When the y^* crosses a threshold α_j, the country club membership shifts.

5.4 Results and Discussion

Before proceeding with the presentation and analysis of the preliminary tests, it is interesting to observe the evolution of the energy intensity (EI) in the LAC. This evolution can be seen in Figure 5.1.



Notes: This graph was achieved through Stata "twoway graphs" features; The blue dots represent the energy intensity (EI) values of each country in the respective year (ei), while the red "diamonds" represent the mean of the energy intensity (EI) value for the region (ei_mean1).

Figure 5.1 – Energy Intensity in LAC

According to Figure 5.1, the overall energy intensity (EI) of the LAC region has been in a decreasing trend since 1970, with only a few periods of exception. This appears to

indicate that the LAC region has managed to increase its energy consumption productivity, following the trend of doing more with less.

In fact, according to some past studies (e.g. Balza et al., 2016), LAC is becoming one of the least energy-intensive regions in the world. This evolution makes the investigation of the LAC energy intensity determinants even more appealing, especially because this seems to have happened without the implementation of regular and significant energy-saving programmes (Balza et al., 2016).

As it was already stressed, the LAC physical capital can be among the factors that could be important determinants of the LAC energy intensity. Indeed, it is believed that newer and more efficient capital equipment can make an essential contribution to the decrease in energy intensity (Voigt et al., 2014). However, as is noted in the book by Araújo et al. (2016), the LAC countries' low total factor productivity (TFP) usually discourages investment in new equipment and infrastructure (which can lead to the previous effect not occurring).

After these brief observations, it is time to move forward and turn the attention to the analysis of the results from this chapter's estimations. This analysis can start with the assessment of the descriptive statistics, which are displayed in Table 5.2.

Table 5.2 – Descriptive statistics

Variables	Descriptive statistics				
	Obs	Mean	Std. Dev.	Min.	Max.
LEI	945	5.246113	0.7797871	3.147825	6.898546
LKPUB	945	4.0292	0.698626	2.054651	5.52382
LKPRIV	945	4.927698	0.336838	4.141868	5.789673
LYPC	945	-11.75664	0.7540923	-13.34477	-9.048695
LCO2PC	945	0.3358615	0.9066564	-3.230116	2.041447
LEP	945	3.636263	0.6506555	2.061044	4.685315
DLEI	924	-0.0206048	0.1171919	-1.312275	0.8867016
DLKPUB	924	0.0040989	0.0519413	-0.1795859	0.3264704
DLKPRIV	924	0.0032835	0.0470015	-0.1878452	0.3207264
DLYPC	924	0.015127	0.0423243	-0.3375359	0.1506739
DLCO2PC	924	0.017039	0.1094636	-0.8105836	1.080082
DLEP	924	0.0564872	0.2550738	-0.6603057	0.9982629

Notes: Obs., Observations; Std. Dev., Standard Deviation; Min., Minimum, Max, Maximum; Stata command *sum* was used to compute the descriptive statistics.

After the assessment of the descriptive statistics, the next step was to compute the cross-section dependence (CD) test (Pesaran, 2004), which allows investigating the possible presence of cross-sectional dependence in the variables. The results from the cross-section dependence (CD) test are displayed in Table 5.3.

Table 5.3 – CD-test

Variables	Cross-section dependence (CD) test		
	CD-test	Corr	Abs(corr)
LEI	27.64***	0.284	0.575
LKPUB	17.01***	0.175	0.476
LKPRIV	11.25***	0.116	0.427
LYPC	50.88***	0.523	0.702
LCO2PC	45.47***	0.468	0.566
LEP	n.a.	n.a.	n.a.
DLEI	2.54**	0.026	0.122
DLKPUB	22.01***	0.229	0.254
DLKPRIV	21.31***	0.222	0.242
DLYPC	22.75***	0.237	0.252
DLCO2PC	3.73***	0.039	0.138
DLEP	n.a.	n.a.	n.a.

Notes: Corr., Correlation; Abs. (corr.), Absolute Correlation; the CD-test has N (0,1) distribution under the H0: cross-section independence; ***, ** denote statistical significance at 1% and 5% level, respectively; the Stata command *xtcd* was used to compute the CD-test.

Looking at the results from the CD-test (Table 5.3), it appears that all variables reject the null hypothesis of cross-section independence. In other words, there seems to exist a correlation between the series across the included crosses. This fact can probably be related to the mutual shocks that the countries from the sample share. Before proceeding, it is also important to note that the variable EP has common values for all countries. This issue makes the applicability of the CD-test for the EP variable null.

After the CD-test, the following procedure was to investigate the order of integration of the variables. To accomplish this objective, it was used the cross-sectionally augmented Im, Pesaran and Shin (CIPS) (Pesaran, 2007b), also called the second-generation unit root test. The results from the CIPS test are displayed in Table 5.4.

Table 5.4 – CIPS test

Variables	CIPS (Zt-bar)	
	Without trend	With trend
LEI	-2.215**	0.522
LKPUB	1.701	0.409
LKPRIV	-1.208	-1.003
LYPC	-2.016**	-1.493*
LCO2PC	-2.141**	1.277
LEP	n.a.	n.a.
DLEI	-13.011***	-12.128***
DLKPUB	-8.813***	-8.096***
DLKPRIV	-10.698***	-9.044***
DLYPC	-10.575***	-8.962***
DLCO2PC	-14.531***	-13.260***
DLEP	n.a.	n.a.

Notes: ***,** and * denote statistical significance at the 1%, 5%, 10% levels, respectively; n.a. denotes not applicable; CIPS assumes that cross-sectional dependence is in the form of a single unobserved common factor and H0: series is I(1); the Stata command *multipurt* was used to compute this test.

The use of CIPS was mainly linked with the fact that, as we stressed in the previous chapters, it is robust to the presence of cross-sectional dependence. Following Neves et al. (2018, p. 31), when cross-sectional dependence is present in the variables, the first-generation unit root tests "*are not trustworthy*" and, because of this fact, the CIPS test should be performed.

Looking at the outcomes of Table 5.4, none of the variables seems to be I(2). In fact, they all seem to be stationary, at least at first differences. Moreover, some of them appear to be on the borderline between the I(0)/I(1) orders of integration. This last observation can be considered as one additional reason to use the PARDL methodology.

As was already stressed, the variable EP is different from all the other variables. It has the same values for all countries during the entire time horizon of this study. This fact makes it closer to a time series variable, which is common to all the countries under study.

Given the previously described characteristic, the augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1981) and Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) (Kwiatkowski et al., 1992) tests were applied exclusively to investigate the order of integration of the EP variable. The results from the ADF and KPSS tests, displayed in Table 5.5, demonstrate that the order of integration of this variable seems to be I(1).

Table 5.5 – ADF and KPSS unit root tests

	KPSS		ADF		
	Trend and Intercept	Intercept	Trend and Intercept	Intercept	None
LEP	0.106475	0.476712**	-2.233689	-2.154676	1.056519
DLEP	0.13579	0.163361	-6.59566***	-6.625773***	-6.429993***

Notes: *** and ** denote statistical significance at 1% and 5%, respectively; KPSS has the following null hypothesis, H0: the process is stationary; ADF has the following null hypothesis, H0: process has unit root (i.e. is not stationary); the statistical software E-Views 10 was used to compute both the KPSS and ADF tests.

After the analysis of the variables' order of integration, the following test that was computed was the second-generation cointegration test of Westerlund (2007). This test allows checking for cointegration or, in other words, test for long-run relationships between the variables. The null hypothesis of this test is "no cointegration". The results of the Westerlund cointegration test can be seen in Table 5.6.

Table 5.6 – Westerlund cointegration test

			None	
Statistics	Value	Z value	p-value	Robust p-value
Gt	-1.801	1.790	0.963	0.626
Ga	-5.343	3.808	1.000	0.959
Pt	-6.481	1.752	0.960	0.691
Pa	-3.241	2.761	0.997	0.919
			Constant	
Statistics	Value	Z value	p-value	Robust p-value
Gt	-2.346	1.444	0.926	0.419
Ga	-9.387	3.107	0.999	0.763
Pt	-7.710	2.928	0.998	0.784
Pa	-4.536	3.728	1.000	0.956
			Constant and Trend	
Statistics	Value	Z value	p-value	Robust p-value
Gt	-2.758	1.277	0.899	0.369
Ga	-9.405	4.901	1.000	0.990
Pt	-8.049	4.736	1.000	0.936
Pa	-4.914	5.469	1.000	0.990

Notes: Bootstrapping regression with 800 reps. H0: No cointegration; H_1 Gt and Ga test the cointegration for each country individually, and Pt and Pa test the cointegration of the panel as a whole; the Stata command *xtwest* was used.

As shown in Table 5.6, the p-values do not reject the null hypothesis of no cointegration for the panel nor for each country individually. As Fuinhas et al. (2017) stress, this could be an additional incentive to use econometric techniques that are less strict about the integration of the variables. One example of these econometric techniques is the PARDL.

5.4.1 Panel Autoregressive Distributed Lag

As it is known, before proceeding with the PARDL estimation, it is necessary to compute a series of specification tests in order to check for the presence of various phenomena in the models. Then, according to the results of these tests, an appropriate estimator will then be chosen to perform the analysis.

Among the several tests that will be conducted, one can start by showing the results from the correlation matrix and the variance inflation factor (VIF) test (Belsley et al., 1980). Their results will allow perceiving if there are correlation or multicollinearity problems that can jeopardize the estimation. The results from both tests are displayed in Table 5.7.

Table 5.7 – Correlation matrices and VIF statistics

	LEI	LKPUB	LKPRIV	LYPC	LCO2PC	LEP
LEI	1.0000					
LKPUB	-0.1621	1.0000				
LKPRIV	-0.1746	0.0183	1.0000			
LYPC	-0.5106	0.1810	-0.0321	1.0000		
LCO2PC	-0.5807	0.2819	0.1355	0.8211	1.0000	
LEP	-0.2210	0.0373	0.1034	0.1758	0.1640	1.0000
VIF		1.10	1.10	3.35	3.54	1.04
Mean VIF		2.03				
	DLEI	DLKPUB	DLKPRIV	DLYPC	DLCO2PC	DLEP
DLEI	1.0000					
DLKPUB	0.2146	1.0000				
DLKPRIV	0.2044	0.7910	1.0000			
DLYPC	-0.2597	-0.7613	-0.8437	1.0000		
DLCO2PC	-0.0590	-0.2505	-0.2604	0.3195	1.0000	
DLEP	-0.0024	-0.0800	-0.0859	0.1348	-0.0425	1.0000
VIF		2.91	4.26	3.97	1.12	1.03
Mean VIF		2.66				

Notes: In the case of the VIF test, the values are lower than the typically assumed benchmarks: 10 in the case of the VIF values, and 6 in the case of the mean VIF values; the Stata commands *corr* and *estat vif* were used to compute the correlation matrix and VIF statistics, respectively.

As it can be seen in Table 5.7, overall, the correlation between the variables seems not to cause significant concerns to the estimation. A possible exception can be the correlation values between LYPC and LCO2PC and between DLYPC and DLKPRIV. However, given that the low VIF and mean VIF values strongly support the absence of multicollinearity problems, the estimation can proceed without further worries (the VIF and mean VIF values are lower than the accepted benchmarks of 10 and 6, respectively).

The following step was to compute the Hausman test (Hausman, 1978) in order to compare the random effects (RE) and the fixed effects (FE) specifications. In Table 5.8, the results from the Hausman test and the Hausman test with the "*sigmamore*" and "*sigmaless*" options are all presented.

Table 5.8 – Hausman tests (FE vs. RE)

Hausman test	Hausman test with *sigmamore*	Hausman test with *sigmaless*
FE vs RE	FE vs RE	FE vs RE
Chi2(12) = 45.77***	Chi2(9) = 42.43***	Chi2(9) = 44.06***

Notes: *** denotes significance at the 1% level; H0: difference in coefficients not systematic/RE is preferable; the Stata command *hausman* (with and without the *sigmamore* and *sigmaless* options) was used to compute this test.

From the achieved chi-square (Chi2) statistics (Table 5.8), the null hypothesis of the Hausman test is rejected for all the specifications (with and without the "*sigmamore*" and "*sigmaless*" options). This means that the FE specification seems to be the most suitable specification for the model's estimation.

However, when working upon macro panels, there is another characteristic that should be tested: panel heterogeneity/homogeneity. As the mean group (MG) and pooled mean group (PMG) estimators, developed by Pesaran and Smith (1995) and by Pesaran et al. (1999), respectively, are usually used to deal with the slope heterogeneity of parameters, there is the need to confront the MG, PMG, and FE estimators. The results from the Hausman test between the MG, PMG, and FE estimators are exhibited in Table 5.9.

Table 5.9 – Hausman tests (MG vs. PMG vs. FE)

Hausman test	MG vs PMG
	Chi2(13) = 12.26
	PMG vs FE
	Chi2(13) = 4.94
	MG vs FE
	Chi2(13) = 0.81

Notes: H0: difference in coefficients not systematic; the Stata commands *xtpmg* and h*ausman* (with the options *sigmamore alleqs constant*) were used.

From the three Hausman tests that were computed (Table 5.9), it is concluded that for MG vs PMG, PMG is the preferable estimator, whereas, for PMG vs FE and MG vs FE, the FE is preferable. The null hypothesis is similar to the previous one (RE vs FE); however, instead of the RE being preferable, the null is that the PMG is the most suitable for MG vs PMG, and FE is the most suitable for PMG vs FE and MG vs FE.

These results mean that there is strong evidence that the panel is homogeneous or that the slope heterogeneity of parameters was not verified, given that the FE seems to be the most suitable estimator. Accordingly, it can continue to be assumed that the FE specification seems to be the most suitable specification for the model's estimation.

Nevertheless, before the presentation of the PARDL model, there are still some phenomena that need to be tested. Therefore, a battery of specification tests was computed for the PARDL model from Equation (5.2) with FE, namely:

- the time fixed effects test;
- the modified Wald test (Greene, 2002);
- the Pesaran test for cross-sectional independence (Pesaran, 2004);
- the Frees' test of cross-sectional independence (Frees, 1995, 2004);
- the Friedman's test of cross-sectional independence (Friedman, 1937);

- the Breusch and Pagan Lagrangian Multiplier (LM) test of independence (Breusch and Pagan, 1980);
- the Wooldridge test (Wooldridge, 2002).

The results from these tests will allow perceiving if time fixed effects are needed in the model (time fixed effects test) and if group-wise heteroscedasticity (modified Wald test), contemporaneous correlation/cross-sectional dependence (Pesaran, Frees', Friedman, and Breusch and Pagan LM tests) and serial correlation/first-order autocorrelation (Wooldridge test) are present in the model. The results from all these tests (as also their null hypotheses) are displayed in Table 5.10.

Table 5.10 – Specification tests

	Statistics
Time fixed effects	1.13
Modified Wald test	1732.95***
Pesaran's test	0.019
Frees' test	0.185***
Friedman's test	46.863***
Breusch Pagan LM test	238.332*
Wooldridge test	64.428***

Notes: * and *** denote statistical significance at the 10% and 1% levels, respectively; H0 of Time fixed effects test: dummies for all years are equal to 0 (no time fixed effects are needed); H0 of modified Wald test: sigma(i)^2 = sigma^2 for all I; H0 of Pesaran's, Frees', Friedman's, and Breusch-Pagan LM tests: residual are not correlated; H0 of Wooldridge test: no first-order autocorrelation; to compute these tests, the Stata commands *testparm*, *xttest3*, *xtcsd*, *xttest2*, *xtserial* were used, respectively.

Following the outcomes from Table 5.10, no time fixed effects are needed. However, there is a strong signal of the presence of group-wise heteroscedasticity, cross-sectional dependence and first-order autocorrelation in the model. In fact, although the Pesaran test of cross-sectional independence seems to point to that the residuals are not correlated across entities, the remaining tests support the idea that there is cross-sectional dependence in the model.

Given the previous outcomes, the Driscoll and Kraay (1998) estimator (DK) with FE was selected to estimate the model. This estimator seems to be the most suitable because it produces standard errors robust to the presence of heteroscedasticity, cross-sectional dependence and first-order autocorrelation. The results from the estimation of the PARDL model from Equation (5.2) with the DK-FE estimator are presented in Table 5.11.

Table 5.11 – PARDL estimation results

Dependent Variable: DLEI	
Constant	-0.0134154
TREND	-0.0015759***
DLKPUB	0.1490815
DLKPRIV	-0.2467661
DLYPC	-0.790175***
DLCO2PC	0.031556
DLEP	0.0287212*
LEI (-1)	-0.0728701***
LKPUB (-1)	0.017512
LKPRIV (-1)	0.0313937*
LYPC (-1)	-0.0116969
LCO2PC (-1)	-0.0467759***
LEP (-1)	0.0208794***
Diagnostic statistics	
N	924
R^2	0.1125
F	F(12, 43) = 34.80***

Notes: ***, ** and * denote statistical significance at the 1%, 5%, and 10% levels, respectively; the Stata command *xtscc* was used to estimate the model.

It is important to note that Table 5.11 does not display the long-run elasticities. They had to be calculated. To achieve the long-run elasticities, it had to be computed a ratio between the variable's coefficients and the LEI coefficient both lagged once and multiply the achieved ratio by "- 1".

The long-run elasticities are now displayed in Table 5.12, jointly with the short-run impacts and the model's adjustment speed. The adjustment speed corresponds to the ECM term, which is the LEI (-1) variable coefficient.

Table 5.12 – Elasticities, short-run impacts, and speed of adjustment

Dependent Variable: DLEI	
Short-run impacts	
DLKPUB	0.1490815
DLKPRIV	-0.2467661
DLYPC	-0.790175***
DLCO2PC	0.031556
DLEP	0.0287212*
Long-run (computed) elasticities	
LKPUB (-1)	0.2403187*
LKPRIV (-1)	0.4308173*
LYPC (-1)	-0.1605173
LCO2PC (-1)	-0.6419077***
LEP (-1)	0.286529***
Speed of adjustment	
ECM	-0.0728701***

Notes: *** and * denote statistical significance at the 1% and 10% levels, respectively; the ECM denotes the coefficient of the variable LEI lagged once.

After performing a first estimation of the PARDL model with the DK-FE estimator, it was observed that the variables DLKPUB, DLKPRIV, DLCO2PC and LYPC were all not statistically significant. This fact led to the removal of these variables from the model,

following the principle of parsimony (Santiago et al., 2020). Thus, the PARDL model from Equation (5.2) was replaced by:

$$DLEI_{it} = \alpha_i + \delta_{1i}TREND_t + \beta_{1i}DLYPC_{it} + \beta_{2i}DLEP_{it} + \gamma_{1i}LEI_{it-1} + \gamma_{2i}LKPUB_{it-1} + \gamma_{3i}LKPRIV_{it-1} + \gamma_{4i}LCO2PC_{it-1} + \gamma_{5i}LEP_{it-1} + \varepsilon_{it} \quad (5.4)$$

The model was then re-estimated without the variables DLKPUB, DLKPRIV, DLCO2PC and LYPC, in accordance with the parsimonious specification (Equation (5.4)). All specification tests were redone to ensure that all assumptions remained the same (see Table A5.1, Table A5.2, and Table A5.3 in Appendix). The results from the parsimonious model (Equation (5.4)) with the DK-FE estimator are presented in Table 5.13.

Table 5.13 – PARDL estimation results – Parsimonious model

Dependent Variable: DLEI	
Constant	0.0571923
TREND	-0.0017403***
DLYPC	-0.6522905***
DLEP	0.0281748*
LEI (-1)	-0.0705164***
LKPUB (-1)	0.0258047**
LKPRIV (-1)	0.0358277**
LCO2PC (-1)	-0.0510826***
LEP (-1)	0.0216925***
Diagnostic statistics	
N	924
R^2	0.1097
F	F(8, 43) = 36.05***

Notes: ***, ** and * denote statistical significance at the 1%, 5%, and 10% levels, respectively; the Stata command *xtscc* was used to estimate the model.

Once again, it is important to note that, as in the case of Table 5.11, Table 5.13 does not display the long-run elasticities. Again, they had to be calculated. The long-run elasticities are now displayed in Table 5.14, jointly with the short-run impacts and the model's adjustment speed, i.e. the ECM term.

Table 5.14 – Elasticities, short-run impacts, and speed of adjustment – Parsimonious model

Dependent Variable: DLEI	
Short-run impacts	
DLYPC	-0.6522905***
DLEP	0.0281748*
Long-run (computed) elasticities	
LKPUB (-1)	0.3659384***
LKPRIV (-1)	0.5080759***
LCO2PC (-1)	-0.7244074***
LEP (-1)	0.3076233***
Speed of adjustment	
ECM	-0.0705164***

Notes: *** and * denote statistical significance at the 1% and 10% levels, respectively; the ECM denotes the coefficient of the variable LEI lagged once.

Looking at the outcomes from Tables 5.12 and 5.14, the results from the non-parsimonious and parsimonious models are quite similar. The variables DLYPC and DLEP seem to be the only variables that demonstrated to have a statistically significant effect on the dependent variable (DLEI) in the short-run. However, whereas DLYPC seems to contribute to a reduction in the energy intensity of the LAC countries, the variable DLEP seems to show an opposite effect, contributing to an increase in these countries' energy intensity.

Concerning the long-run analysis, firstly, both the interest variables, LKPUB and LKPRIV, seem to contribute to the increase of long-run LAC energy intensity (the statistical significances are higher in the most parsimonious model). However, LKPRIV shows an effect with a relatively larger magnitude than LKPUB. Second, the energy commodity prices (LEP) continues to demonstrate a positive coefficient, meaning that it also has an enhancing effect on the energy intensity of these countries in the long-run. Finally, LCO2PC seems to be the only variable of those included in the models that has a depressing effect on the long-run energy intensity.

Regarding the ECM values, they are negative and statistically significant at the 1% level in both specifications. This suggests that cointegration/long-memory exists between the variables (a fact that contradicts the results of the Westerlund cointegration test in Table 5.6). This outcome is not new, given that this contradiction has already occurred in some previous studies (e.g. Fuinhas et al., 2015, 2017). Finally, it should be stressed that the relatively small ECM coefficient value indicates that the speed at which the dependent variable returns to equilibrium after changes in the independent variables is quite slow.

Discussing the main results from the estimation, as was also found by Jimenez and Mercado (2014) in their study on Latin American countries, income (DLYPC) seems to

be negatively related to energy intensity (DLEI). However, this effect was only noticed in the short-run. This means that, initially, these countries seemed to have taken advantage of their economic development to increase their production processes efficiency. Nevertheless, as Deichmann et al. (2019) stress, when countries reach a certain income level, the income effect on energy intensity seems to vanish, and the development and application of energy efficiency policies start to be much more critical for reducing energy intensity.

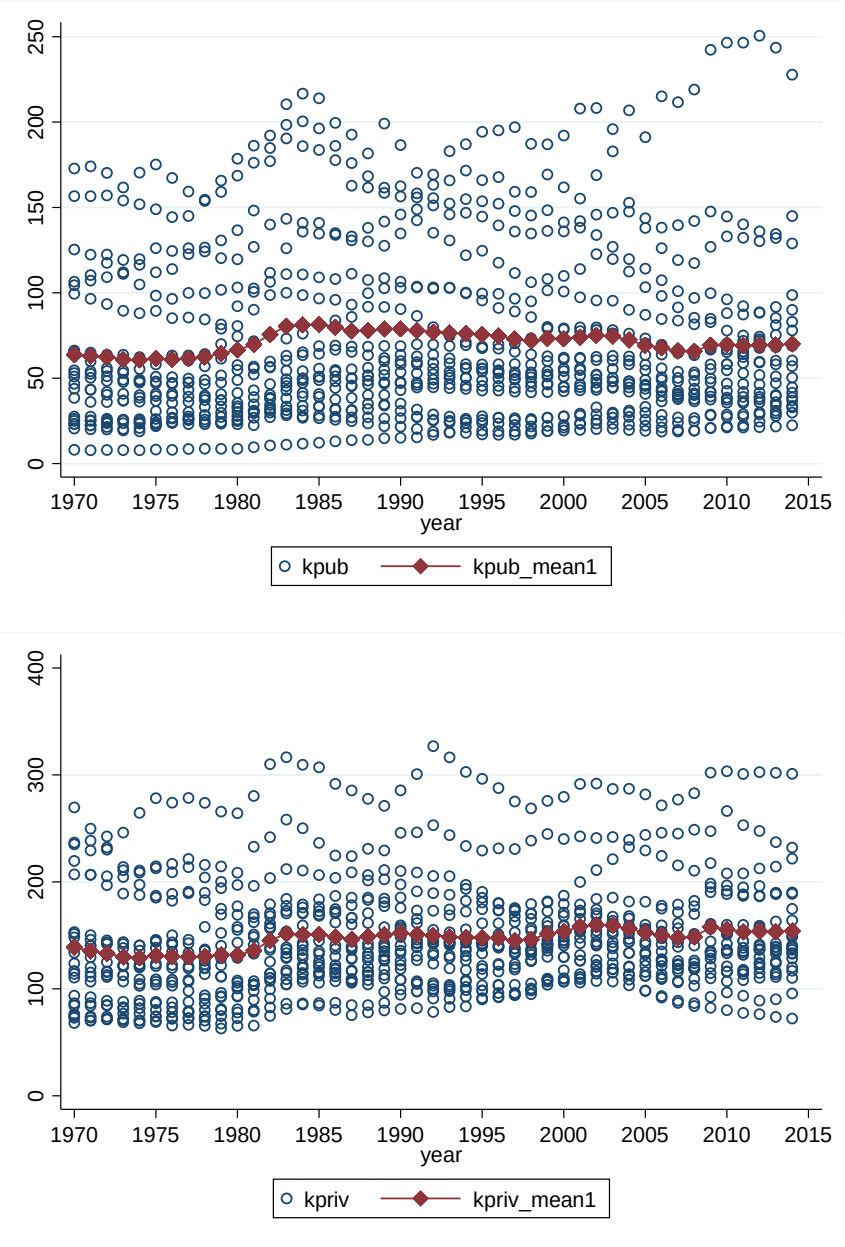
A result that suggests the importance of developing policies to decrease energy intensity is that of LCO2PC. As can be seen in Tables 5.12 and 5.14, CO2 emissions are shown to have a negative impact on energy intensity (DLEI), contributing to its decrease in the long-run. Hence, it can be said that the problems related to environmental pressure (in this case, proxied by CO2 emissions per capita) create incentives for governments to develop policies and more environmentally friendly technology and innovations in order to support the environmental and energy sustainability of their countries (Khan et al., 2019, 2020). Therefore, the development of, for example, energy efficiency policies, due to the pressures exerted by factors as CO2 emissions, can probably explain the achieved outcome.

Concerning energy commodities prices (LEP and DLEP), the results showed that they increase energy intensity (DLEI) both in the short- and long-run. This outcome implies that the higher energy commodities prices induce the LAC countries to increase their rents. A significant part of them has abundant energy commodities, leading to higher energy consumption from their economies. Ultimately, this fact can drive to an increase in energy intensity. A similar result was found for OPEC in the case of oil prices (Samargandi, 2019).

Now, regarding the variables of interest, the public (LKPUB) and private (LKPRIV) capital stocks, it seems that they are far from being responsible for the decreasing trend of LAC energy intensity. In fact, the results point to an enhancing effect from both types of capital on energy intensity (DLEI) in the long-run. These outcomes seem to follow the view held by Araújo et al. (2016) that there is a lack of investment in new equipment and infrastructure in the LAC countries.

Moreover, the fact that this effect is primarily captured in the long-run probably means that the intensification of the LAC economic activity was not accompanied by the investment in more energy-efficient capital stock. Over time, the effect of this lack of investment on these countries' energy intensity has become more and more significant.

To corroborate these statements, the evolution of the LAC KPUB and KPRIV from 1970 to 2014 are presented in Figure 5.2.



Notes: This graph was achieved through Stata "twoway graphs" features; The blue dots represent the public capital stock (kpub) and private capital stock (kpriv) values of each country in the respective year, while the red "diamonds" represent the mean of the public capital stock (kpub_mean1) and private capital stock (kpriv_mean1) value for the region.

Figure 5.2 – Public capital stock and private capital stock in LAC (% of GDP)

As can be perceived by the graphs in Figure 5.2, the LAC public and private capital stocks levels have followed a steady trend since the 1970s. This raises some doubts about the capacity of the LAC region to invest in new (and more efficient) physical capital. Some

previous studies also point to another problem regarding the LAC physical capital development: the lack of maintenance of their existing capital stock (Faruqee, 2016).

All these issues seem to lead to the assumption that the LAC physical capital does not contribute to the decrease in the regional energy intensity. It seems that the LAC physical capital is still very energy-intensive and needs to be upgraded, both in the public and private sectors. Outdated capital seems to prevent this region from reaching an even lower energy intensity level.

5.4.2 Convergence Clubs

The first step of the convergence analysis of Phillips and Sul (2007) is to test the convergence hypothesis for the whole sample through the log t regression test. However, before the estimation, the cyclical component should be removed from the series. Accordingly, the Hodrick-Prescott filter (Hodrick and Prescott, 1997) was used to remove the trend component from the variable LEI. The log t regression test results are given in Table 5.15.

Table 5.15 – Log t regression test results (whole sample)

Variable	Coefficient	Standard Error	t Statistic
log(t)	-1.6554	0.1023	-16.1778

Notes: H0: convergence for the whole panel; if t statistic < -1.65, H0 is rejected at the 5% level.

As can be seen (Table 5.15), the t statistic value (-16.1778) rejects the null hypothesis of convergence for the whole sample at the 5% significance level (the t statistic is below the critical value of -1.65), meaning that the LAC countries do not converge to the same steady-state equilibrium in terms of energy intensity.

Then, the hypothesis of club convergence within the sample was tested through the club clustering algorithm of Phillips and Sul (2007). This algorithm can be summarised in the following five steps: (1) sorting; (2) core group formation; (3) sieve individuals for club membership; (4) recursion and stopping rule; and (5) club merging. For a more in-depth explanation of these steps, i.e. on how the clubs are identified by the algorithm, see Du (2017) and “Notes on the log t-test and the clustering algorithm” in Appendix B. The results are shown in Table 5.16.

Table 5.16 – Convergence test results of the initial clubs

Clubs	Number of countries	Coefficient	t Statistic	Countries
1	2	-1.181	-1.073	Haiti, Honduras
2	8	0.221	3.088	Argentina, Bolivia, Brazil, Guatemala, Nicaragua, Paraguay, Uruguay, Venezuela
3	7	0.107	0.805	Barbados, Chile, Costa Rica, El Salvador, Grenada, Mexico, Peru
4	2	1.251	1.602	Ecuador, Panama
Divergent group	2	-4.234	-18.893	Colombia, Dominican Republic

Notes: H0: countries in clubs are converging; if t statistic < -1.65, H0 is rejected at the 5% level.

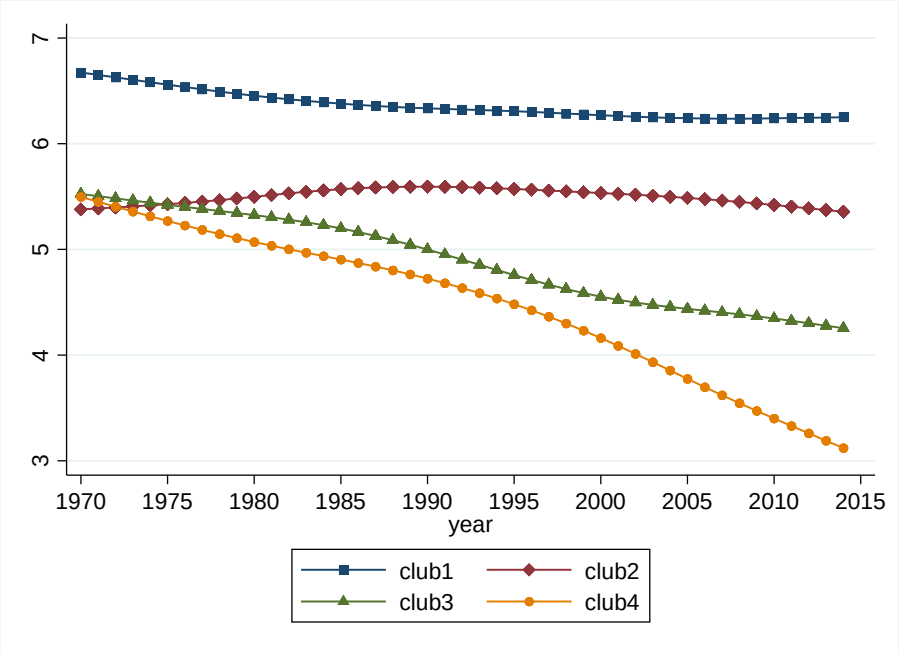
The outcomes from Table 5.16 indicate that there seems to exist four convergence clubs, whose t statistics are higher than -1.65, and one divergent group composed of countries that do not converge to any club (Colombia and Dominican Republic). Additionally, the modified method of Schnurbus et al. (2017) was used to investigate the hypothesis of possible club merging. Its results can be seen in Table 5.17.

Table 5.17 – Club merging test

Clubs	Coefficient	t Statistic
1+2	-0.212	-7.467
2+3	-1.007	-34.056
3+4	-0.911	-11.541
4+5	-3.000	-29.315

Notes: H0: clubs can be merged; if t statistic < -1.65, H0 is rejected at the 5% level.

By these results (Table 5.17), the null hypothesis is rejected for all combinations as the t statistics are all lower than -1.65. This means that the convergence clubs are indeed the ones that were previously achieved. Figure 5.3 shows the averages of the relative energy intensity transition paths for the four identified clubs.



Notes: This graph was achieved through Stata "twoway graphs" features, after the computation of the means of the energy intensity of each club for each year.

Figure 5.3 – Average relative energy intensity transition paths for different convergence clubs

Following the graph from Figure 5.3 and the information from Table 5.18, it can be seen that "Club 1", composed of Haiti and Honduras, has the highest average energy intensity level. Its initial energy intensity is the highest among the clubs. "Club 2", composed by Argentina, Bolivia, Brazil, Guatemala, Nicaragua, Paraguay, Uruguay and Venezuela, comes right after "Club 1", being followed by "Club 3", which is composed by Barbados, Chile, Costa Rica, El Salvador, Grenada, Mexico, and Peru. "Club 4", composed of Ecuador and Panama, has the lowest average energy intensity.

Table 5.18 – Descriptive statistics of the energy intensity of the convergence clubs

Clubs	Obs.	Mean	Std. Dev.	Min.	Max.
1	90	6.364524	0.1284383	6.237211	6.674018
2	360	5.497266	0.0729173	5.356544	5.593428
3	315	4.894103	0.4226166	4.254727	5.524538
4	90	4.479531	0.6945355	3.120902	5.496629

Notes: Obs., Observations; Std. Dev., Standard Deviation; Min., Minimum, Max., Maximum.

Although "Club 2" has an initial energy intensity below that of "Club 3" and "Club 4", its transition path followed a stable tendency between 1970 and 2014. In fact, there was a slight increase until the 1990s. Conversely, looking at the transition paths from "Club 3" and "Club 4", it is seen a robust decreasing tendency which starts right after 1970. From

all the previous information, it can be concluded that the countries in "Club 1" and "Club 2" probably need to make an additional effort to reduce their energy intensity levels.

5.4.3 Ordered Logit

As previously stressed, in addition to the identification of the clubs, it was also employed an ordered logit model to see whether the capital stock is responsible to some extent for the formation of the LAC convergence clubs.

The ordinal response variable, which was named CLUB, is the dependent variable, representing the club to which a determined country belongs, taking values from 1 to 4. This variable is an ordinal variable because the clubs can be ranked following their energy intensity, i.e. the higher the value, the lower the energy intensity (see Table 5.18).

In the ordered logit model, two specifications were considered, following Bai et al. (2019a) and Matysiak and Olszewski (2019): 1) with the averages of the public and private capital stocks in the percentage of the GDP between 1970 and 2014 (KPUB_M and KPRIV_M); and 2) with the public capital stock and private capital stock annual % averages over 1970-2014 (KPUB_G and KPRIV_G). The data on public and private capital stocks from the IMF (2017) "*Investment and Capital Stock Dataset*" in billions of constant 2011 international dollars was used to calculate the annual % averages.

The variable initial energy intensity (EI_1), which represents the countries' energy intensity in 1970, was chosen as the control variable following the study of Yu et al. (2015). Yu et al. (2015) followed the principle that states that similar initial conditions are an essential factor for convergence (Galor, 1996). The results from the ordered logit estimation are displayed in Table 5.19.

Table 5.19 – Ordered logit estimation results

Dependent Variable: CLUB			
Specification 1		Specification 2	
EI_1	-0.0039757**	EI_1	-0.0038458***
KPUB_M	-0.0071272	KPUB_G	0.1807698
KPRIV_M	0.0096617	KPRIV_G	0.1400534
Diagnostic statistics		Diagnostic statistics	
N	19	N	19
Pseudo R^2	0.1217	Pseudo R^2	0.0973
Log pseudolikelihood	-20.126745	Log pseudolikelihood	-20.685004
Wald chi2(3)	7.58	Wald chi2(3)	7.87
Prob > chi2	0.0556	Prob > chi2	0.0488
Brant test	1.17	Brant test	3.26

Notes: ** and *** denote statistical significance at the 5% and 1% levels, respectively.

Looking at the results from Table 5.19, EI_1 seems to be an essential determinant for the country's membership in a specific club. The negative coefficient in both specifications means that a positive change in the initial energy intensity reduces the probability of being a member of a low-energy intensity club. Conversely, it also means that a higher initial energy intensity increases the chance of a certain country belonging to clubs with a high energy intensity level. This result is in accordance with past empirical investigations Yu et al. (2015).

Regarding the variables KPUB_M and KPRIV_M, and KPUB_G and KPRIV_G, none of them was demonstrated as having a statistically significant effect. This means that they are not determinants of club membership. The possible explanations for this lack of effect can be that, first, as seen above, both types of capital have an enhancing effect on the LAC energy intensity (see Tables 5.12 and 5.14). In contrast, the tendency is for countries (and clubs) to converge to a lower level of energy intensity in the long-run (see Figure 5.3). Second, the evolution of both types of capital and their subsequent effects on energy intensity may be similar in most countries under analysis, meaning that capital stock is not a differentiating factor in club formation. Therefore, it can be said that there is a reinforcement that the conclusions regarding the need for new physical capital investments can be applied to all countries.

5.5 Conclusion and Policy Implications

Different methodologies were used to analyse the role of public and private capital stock on the energy intensity of a group of 21 LAC countries. First, a PARDL model was used to investigate the short- and long-run impacts of public and private capital stocks on these countries' energy intensity.

Given that cross-section dependence, heteroscedasticity, and first-order autocorrelation were present in the PARDL model, the Driscoll and Kraay estimator (with fixed effects) had to be used to control for the presence of all these phenomena. As the variables DLKPUB, DLKPRIV, DLCO2PC and LYPC were all not statistically significant (Table 5.12), the PARDL was re-estimated without these variables to produce a parsimonious version of the model (Equation (5.4)). Nevertheless, the results from the non-parsimonious (Table 5.12) and parsimonious model (Table 5.14) were very similar.

Concerning the interest variables, the outcomes pointed to an enhancing effect from both public and private capital stocks on these countries' long-run energy intensity. This can be a sign of the lack of investment in newer and more energy-efficient physical capital in the LAC region over the years. In sum, it points to the fact that the LAC physical capital

is still very energy-intensive and needs to be upgraded, both in the public and private sectors.

Regarding the control variables, the outcomes from the PARDL models pointed to a decreasing effect from income on energy intensity in the short-run. Additionally, they also have pointed to the fact that the CO2 emissions seem to have contributed to the decrease in the LAC energy intensity in the long run. Finally, energy commodity prices seem to have induced the LAC countries to increase their energy intensity levels both in the short- and long-run.

In the next step of this investigation, the log t regression test method and the club clustering algorithm were used to identify the LAC countries that converge to different equilibriums in terms of energy intensity. The outcomes showed that the 21 LAC countries do not converge to the same steady-state equilibrium in terms of energy intensity. In fact, four convergence clubs and one divergent group (composed by countries that do not converge to any club) were identified: “Club 1” composed of Haiti and Honduras; “Club 2” composed of Argentina, Bolivia, Brazil, Guatemala, Nicaragua, Paraguay, Uruguay and Venezuela; “Club 3” composed by Barbados, Chile, Costa Rica, El Salvador, Grenada, Mexico and Peru; “Club 4” composed by Ecuador and Panama; with the divergent group being composed by Colombia and the Dominican Republic.

As was noted, the clubs were ordered by their energy intensity levels (Table 5.18), with “Club 1” being the most energy-intensive club and the “Club 4” the least energy-intensive. From this information, jointly with the analysis of their average energy intensity transition paths (Figure 5.3), it was concluded that the countries in “Club 1” and “Club 2” seem to need to make an additional effort to reduce their energy intensity levels, mainly when compared with the ones in “Club 3” and “Club 4” where it was noted a stable decreasing trend in energy intensity.

Despite the valuable conclusions from the analysis of the convergence clubs, it should be recalled that this investigation aimed to study the role that public and private capital stocks play in the energy intensity of these LAC countries. Thus, the principal purpose of the convergence club analysis was to find an ordinal response variable (representing the club to which a country belongs) that could be used as the dependent variable in an ordered logit regression model. Then, the objective was to use that same model to investigate if the capital stocks were responsible for the formation of the LAC energy intensity convergence clubs.

Looking at the results of the ordered logit model (Table 5.19), it was found that, conversely to these countries' initial energy intensity, none of the capital stocks was a determinant of club membership. As public and private capitals do not drive the formation of convergence clubs, this means that the difference of these clubs, in terms of energy intensity, comes from other factors. Moreover, this probably means that the effects from both types of capital on energy intensity are similar in most of the countries under analysis. This outcome supports the conclusions previously drawn from the PARDL estimation: investment in newer and more energy-efficient physical capital is needed in all the countries of this region, regardless of their club membership.

Based on these results and conclusions, the LAC governments should increase investment in more energy-efficient physical capital. This investment focused on the improvement of the region's energy efficiency and on the region's energy intensity decrease, should not only be made on their infrastructures but also on the equipment and machines that are used in the LAC production process (with particular attention to the most energy-intensive economic sectors). In order to achieve a suitable and satisfactory investment level, the LAC governments will probably need to improve their public financing instruments and, if necessary, call upon institutional investors.

At the same time, they should create (or improve) the laws and the regulatory framework regarding energy efficiency (e.g. setting energy efficiency targets for their various economic sectors, developing energy efficiency norms and regulation for equipment and appliances, setting efficiency standards and promoting energy audits for buildings/infrastructures). In some cases, it could be easier to invest in the maintenance and upgrade of the existing capital than to invest in new physical capital.

Additionally, based on the analysis outcomes, it is also necessary that the LAC governments create incentives to enable private physical capital to follow the same tendency. Although the improvement in public sector energy efficiency could influence the private sector to follow a similar tendency, some additional measures should be developed in order to accelerate this process. As examples of the tools that can be used to achieve this end, it can be stated the development of new financing schemes, such as loans and lines of credit strictly directed to investment in energy efficiency projects and the creation (or improvement) of financial incentives as subsidies and/or fiscal incentives for energy efficiency investments (e.g., tax reductions, tax credits, among others). Moreover, it is also advisable that financial institutions complement the governments' efforts when it comes to supporting energy efficiency investment projects in the private sector.

Finally, given that investment in more energy-efficient physical capital is a necessity for the whole LAC region and that the regional energy transition will depend on not only the shift to renewables but also on a significant increase in the region's energy efficiency, the discussion, creation and promotion of measures focused on the transition of this region to more efficient energy use should be firmly present on the agendas of regional organisations such as the Economic Commission for Latin America and the Caribbean (ECLAC), and the *Organización Latinoamericana de Energia* (OLADE). These regional organisations should serve as a stage for creating and promoting energy efficiency measures for the LAC region and can contribute to creating a more homogeneous energy efficiency promotion plan for this region.

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Appendix

Table A5.1 – Hausman tests (FE vs RE) – Parsimonious model

Hausman test	Hausman test with *sigmamore*	Hausman test with *sigmaless*
FE vs RE	FE vs RE	FE vs RE
Chi2(8) = 44.18***	Chi2(5) = 43.79***	Chi2(5) = 45.74***

Notes: *** denotes statistical significance at the 1% level; H0: difference in coefficients not systematic/RE is preferable; the Stata command *hausman* (with and without the *sigmamore* and *sigmaless* options) was used to compute this test.

Table A5.2 – Hausman tests (MG vs PMG vs FE) – Parsimonious model

Hausman test	MG vs PMG
	Chi2(9) = 22.74***
	PMG vs FE
	Chi2(9) = 1.60
	MG vs FE
	Chi2(9) = 0.17

Notes: *** denotes statistical significance at the 1% level; H0: difference in coefficients not systematic; the Stata commands *xtpmg* and *hausman* (with the options *sigmamore alleqs constant*) were used.

Table A5.3 – Specification tests – Parsimonious model

	Statistics
Time fixed effects	1.12
Modified Wald test	1687.97***
Pesaran's test	-0.073
Frees' test	0.183***
Friedman's test	48.969***
Breusch Pagan LM test	242.808*
Wooldridge test	64.217***

Notes: * and *** denotes statistical significance at the 10% and 1% levels, respectively; H0 of Time fixed effects test: dummies for all years are equal to 0 (no time fixed effects are needed); H0 of Modified Wald test: sigma(i)^2= sigma^2 for all I; H0 of Pesaran's, Frees', Friedman's, and Breusch-Pagan LM tests: residual are not correlated; H0 of Wooldridge test: no first-order autocorrelation; to compute these tests, the Stata commands *testparm*, *xttest3*, *xtcsd*, *xttest2*, *xtserial* were used, respectively.

Notes on the log t-test and the clustering algorithm

The log t-test proposed by Phillips and Sul (2007) is based on a time-varying factor representation of the interest variable (in our case the EI_{it}), which can be decomposed into a systematic element g_{it} and a transitory element a_{it} as follows:

$$EI_{it} = g_{it} + a_{it} \quad \text{(A5.1)}$$

In Equation (A5.1), the parameters g_{it} and a_{it} can be linear, nonlinear, stationary or nonstationary, given that this specification does not impose any parametric functional form. In addition, it is also important to note that this specification allows for common and idiosyncratic components in both g_{it} and a_{it}. In order to separate these components (common and idiosyncratic), Phillips and Sul (2007) transformed the Equation (A5.1) as follows:

$$EI_{it}=\left(\frac{g_{it}+a_{it}}{\mu_t}\right)\mu_t=\delta_{it}\mu_t, \text{ for all } i \text{ and } t, \tag{A5.2}$$

where μ_t is a single common component, which is assumed to have some deterministic or stochastic trend behavior, while δ_{it} is the time-varying heterogeneous element that measures the deviation of EI_{it} from the trend component μ_t. The relative transition coefficients can be estimated through the elimination of the common component μ_t, rescaling EI_{it} cross-sectionally, so that:

$$h_{it}=\frac{EI_{it}}{\frac{1}{N}\sum_{i=1}^{N}EI_{it}}=\frac{\delta_{it}}{\frac{1}{N}\sum_{i=1}^{N}\delta_{it}}, \tag{A5.3}$$

where h_{it} is the relative transition parameter which measures the value of δ_{it} for economy i in period t in relation to a cross-sectional average. By equation (A5.3), the cross-sectional mean of h_{it} is 1, and if $\delta_{it}\to\delta$ and $t\to\infty$ for all i, then the cross-sectional variance of h_{it} meet the following condition:

$$H_{it}=\frac{1}{N}\sum_{i=1}^{N}(h_{it}-1)^2\to 0 \tag{A5.4}$$

Based on the assumptions on δ_{it}:

$$\delta_{it}=\delta_i+\sigma_{it}\xi_{it}, \sigma_{it}=\frac{\sigma_i}{L(t)t^{\alpha}}, t\geq 1, \sigma_i>0 \text{ for all } i\,, \tag{A5.5}$$

where δ_i is fixed, σ_i is an idiosyncratic scale parameter fixed over time, ξ_{it} is iid (0, 1), $L(t)$ is a slowly varying function, and α denotes the decay rate, Phillips and Sul (2007) proposed the following null hypothesis of convergence:

$$H_0\colon \delta_{it}=\delta_i \text{ for all } i \text{ and } \alpha\geq 0 \tag{A5.6}$$

the alternative hypothesis is then $H_1: \delta_{it} \neq \delta_i$ for some *i* and $\alpha < 0$. If the null hypothesis is not rejected, then the entire sample tends to converge, in our case, this means that the energy intensity (EI) is converging for all countries, if it is rejected, then we have evidences that some convergence clubs may exist (and/or some of the individuals may be divergent). In order to test the null hypothesis, we can use the regression-based convergence test proposed by Phillips and Sul (2007):

$$\log\left(\frac{H_1}{H_t}\right) - 2\log\{\log(t)\} = a + b\log(t) + \varepsilon_t \quad \text{for } t = [rT], [rT]+1, \dots, T, \text{ for all } r > 0, \tag{A5.7}$$

by the work of Phillips and Sul (2007), b is equal to 2α (i.e. $b = 2\alpha$), thus allowing the possibility to test the null hypothesis (H_0) by a heteroscedasticity and autocorrelation consistent one-side t-test as follows:

$$t_b = \frac{\hat{b} - b}{s_b} \Rightarrow N(0,1), \tag{A5.8}$$

with $\hat{b}$ being the least-squares estimate of b and s_b being the long-run standard error. If the t statistic shows that $b \geq 0$, then the energy intensities in LAC are converging, otherwise if $b < 0$, then energy intensities are not converging. In other words, the null hypothesis of convergence (H_0) is rejected if $t_b < -1.65$ (the 5% level of significance).

If the null hypothesis is rejected, we can try to identify convergence clubs (i.e. convergence of subgroups) through the clustering algorithm originally proposed by Phillips and Sul (2007) and later modified by Schnurbus et al. (2017). The clustering algorithm can be described in the following steps according to Du (2017, pp.885-887):

1. Sorting;

"Sort individuals in the panel decreasingly according to their observations in the last period. If there is substantial time-series volatility in the data, the sorting can be implemented based on the time-series average of the last fraction (for example, 1/2, 1/3) of the sample. Index individuals with their orders {1,...,N}."

2. Core group formation;

2.1. *"Find the first k such that the test statistic of the log t regression* $t_k > -1.65$ *for the subgroup with individuals {k, k + 1}. If there is no k satisfying* $t_k > -1.65$*, exit the algorithm, and conclude that there are no convergence subgroups in the panel."*

2.2. *"Start with the k identified in step 2.1, perform log t regression for the subgroups with individuals {k, k + 1,...,k + j},* $j \in \{1,...,N-k\}$*. Choose* j^* *such that the subgroup with individuals* $\{k, k+1,...,k+j^*\}$ *yields the highest value of the test statistic. Individuals* $\{k, k+1,...,k+j^*\}$ *form a core group."*

3. Sieve individuals for club membership;

3.1. *"Form a complementary group* $G_{j^*}^c$ *with all the remaining individuals not included in the core group. Add one individual from* $G_{j^*}^c$ *at each time to the core group and run the log t test. Include the individual in the club candidate group if the test statistic is greater than the critical value* c^**."*

3.2. *"Run the log t test for the club candidate group identified in step 3.1. If the test statistic* $\hat{t}_b$ *is greater than –1.65, the initial convergence club is obtained. If not, Phillips and Sul (2007) advocated raising the critical value* c^* *and repeating steps 3.1 and 3.2 until* $\hat{t}_b > -1.65$*. Schnurbus, Haupt, and Meier (2017) proposed adjusting this step as follows: If the convergence hypothesis does not hold for the club candidate group, sort the club candidates w.r.t. decreasing* $\hat{t}_b$ *obtained in step 3.1. If there are some* $\hat{t}_b > -1.65$*, add the individual with the highest value of* $\hat{t}_b$ *to form an extended core group. Add one individual from the remaining candidates at a time, run the log t test, and denote the test statistic* $\hat{t}_b$*. If the highest value of* $\hat{t}_b$ *is not greater than –1.65, stop the procedure; the extended core group will form an initial convergence club. Otherwise, repeat the above procedure to add the individual with the highest* $\hat{t}_b$*."*

4. Recursion and stopping rule;

"Form a subgroup of the remaining individuals that are not sieved by step 3. Perform the log t test for this subgroup. If the test statistic is greater than –1.65, the subgroup forms another convergence club. Otherwise, repeat steps 1–3 on this subgroup."

5. Club merging.

"Perform the log t test for all pairs of the subsequent initial clubs. Merge those clubs fulfilling the convergence hypothesis jointly. Schnurbus, Haupt, and Meier (2017) advocated conducting club merging iteratively as follows: run the log t test for the initial clubs 1 and 2; if they fulfill the convergence hypothesis jointly, merge them to form the new club 1, then run the log t test for the new club 1 and the initial club 3 jointly; if not, run the log t test for initial clubs 2 and 3, etc. The new club classifications would be obtained by the above procedure. After that, one can also repeat the procedure on the newly obtained club classifications until no clubs can be merged, which leads to the classifications with the smallest number of convergence clubs."[1]

[1]All the studies that were cited in this Appendix (Du, 2017; Schnurbus et al., 2017; Phillips and Sul, 2007) are referenced in the "References" section of the respective chapter (Chapter 5).

Chapter 6

Conclusions

Due to the growing evidence that the Latin America and Caribbean (LAC) region suffers from a lack of physical capital (it seems that it suffers from an "*infrastructure gap*") and to the idea that this situation can be detrimental to the region's development, in this thesis we decided to explore the effects that the LAC capital stock has had on the region's development. This was accomplished through the assessment of the capital stock effects on three main variables: economic growth, income inequality, and energy intensity.

As it was previously stressed (in Chapter 1), the reason to choose these variables is linked with the fact that in order to promote the development of this region, LAC governments should not only centre their efforts on the improvement of the economic output of their countries but should also overcome two of the region's most prominent problems: its high inequality levels and its energy demand and energy security worries. Thus, through the analysis of the effects that capital stock has had on the region's economic growth, income inequality, and energy intensity, it was possible to give several suggestions to the LAC policymakers concerning the future public and private physical capital investments so that they could be directed towards the promotion of the economic, social, and sustainable development of the LAC region.

6.1 Concluding Remarks

Four different analyses were performed during the doctoral research to answer this thesis's central question. Consequently, these four analyses gave rise to the four main chapters of this same thesis: Chapter 2 entitled "Latin America and the Caribbean Physical Capital"; Chapter 3 entitled "The relationship between public capital stock, private capital stock, and economic growth in Latin America and Caribbean countries"; Chapter 4 entitled "What effect does public and private capital have on income inequality? The case of the Latin America and Caribbean region"; and Chapter 5 entitled "An analysis of the energy intensity of Latin American and Caribbean countries: Empirical evidence on the role of public and private capital stock".

Initially, the focus of this thesis was on the inference regarding the effects of public capital stock on the region's development. However, as data for private capital was also available, the scope of the analysis was broadened to also account for this variable.

Moreover, it should also be mentioned that all the empirical analyses were based on panel data techniques, with the number of LAC countries included in each one of these analyses being chosen according to the data availability.

In Chapter 2, it was conducted a historical analysis of the evolution of the public and private physical capital in the LAC region from 1970 until 2017, recurring to data from the International Monetary Fund (IMF) on public and private capital for the LAC countries. This chapter was mostly based on a discriminative analysis of the available data. Whereas in the following chapters (Chapter 3, Chapter 4 and Chapter 5), this same data was used to carry out a set of empirical analyses using several econometric methods.

In Chapter 2 analysis, it was noted that the evolution of both types of capital was always influenced by the LAC economic conjuncture. Moreover, it was noted that the LAC public investment was always relatively low, mostly between 4% and 6% of the GDP. It has only surpassed the 6% of GDP on some rare occasions (1979, 1980, 1981). In fact, it was also noticed that that the LAC public investment between 1970 and 2017 was always behind the one from the East Asian and Pacific (EAP), one of its biggest competitors. Regarding the LAC private investment, it seemed to be much more volatile, with larger peaks and breaks, being more sensitive to the economic situation of the LAC than the public investment.

Concerning the evolution of public and private capital stocks as a percentage of GDP, even though both stocks have increased between 1970 and 2017, it was noticed that this evolution was very slow throughout the time. In fact, it was almost constant in some of the periods which were analysed. This reinforces the suspicion of the lack of capacity of the LAC to invest in new physical capital. A suspicion which is also reinforced by the fact that some of the highest shares were registered in years of economic slowdown.

In sum, all these pieces of evidence seem to point to a lack of physical capital investment in LAC. If nothing is done, this can be quite worrying, given that it is believed that this handicap can lead to several negative effects in the LAC economies. In fact, it is believed that it can hamper the region's development.

Thus, to prevent the negative effects of the lack of physical capital and to support the region's development, it is essential that the LAC governments increase their public investment levels in physical capital, namely in infrastructure. At the same time, it is also wise that they improve the planning and management of public investment projects, as also their financing methods. Finally, it also appears to be essential that these

governments develop measures to reduce the volatility of the private investment, primarily because it is necessary to avoid the capital flight phenomenon in times of economic slowdown.

After reaching the previous conclusions, the LAC capital stock and economic growth relationship was then empirically analysed in Chapter 3. To achieve the goals of this chapter, annual frequency data on the gross domestic product (GDP), on general government capital stock (or public capital stock), and on the private capital stock was collected for a group of 30 LAC countries between 1970 and 2014. Data on population (in the total number of persons) was also collected to convert the previously mentioned variables into per capita values. Concerning the empirical analysis of this chapter, it was based on the use of the panel vector autoregression (PVAR) and on the dynamic ordinary least square (DOLS) and the fully modified ordinary least squares (FMOLS) estimators.

There were several reasons for choosing the PVAR to perform the empirical analysis. Among them are that this model has the advantage of not imposing causal relationships, allows to test for the existence of causal relationships in any direction (overcomes the reverse causation problem), and enables indirect links between the variables. Additionally, it also has the advantage of dealing properly with the presence of cointegration and endogeneity.

However, given that the PVAR requires that all variables be stationary of the same order, it is often necessary to transform the variables into first differences. As this transformation leads to the loss of the ability to analyse the long-run relationships between the variables, the PDOLS and PFMOLS estimators were used to circumvent this problem. More precisely, they were used to identify the long-run impacts of the public and private capital stocks on economic growth.

After conducting a series of preliminary tests and specification tests, a first-order PVAR model was then estimated. Its stability was confirmed through the graph of eigenvalues. After the PVAR estimation, the Granger causalities, the forecast error variance decomposition (FEVD) and the impulse response functions (IRFs) were also computed. Finally, the PDOLS and PFMOLS were estimated.

The results from Chapter 3 estimations reveal that, in the long-run, both public and private capital stocks seem to have a positive effect on economic growth. However, in the short-run, only the private capital stock seems to positively affect the LAC countries' growth. In fact, public capital is shown to have a negative effect on both growth and

private capital in the short-run. This last result seems to indicate that appears to exist a crowding-out effect from public capital on private capital in the short-run. Ultimately, this can also be an explanation for the short-run negative effect of public capital on growth.

Following these results, it seems to be important that the LAC governments continue to promote public investment at the same time as they create or improve the conditions to encourage private investment. However, due to the short-run adverse effects from public capital on private capital and economic growth, the LAC governments should be more aware of how the public investment is materialised in their economies. They should guarantee that public investment is planned in a way so that the public and private capital act as complements and not as substitutes.

Additionally, in order to overcome the negative effects that were noticed, it becomes essential that these governments improve the selection, evaluation, and management of their public investment projects. In a similar sense, they should also improve their public financing instruments and/or search for new ways of funding. A schematic of the main conclusions of Chapter 3 is shown in Figure 6.1.

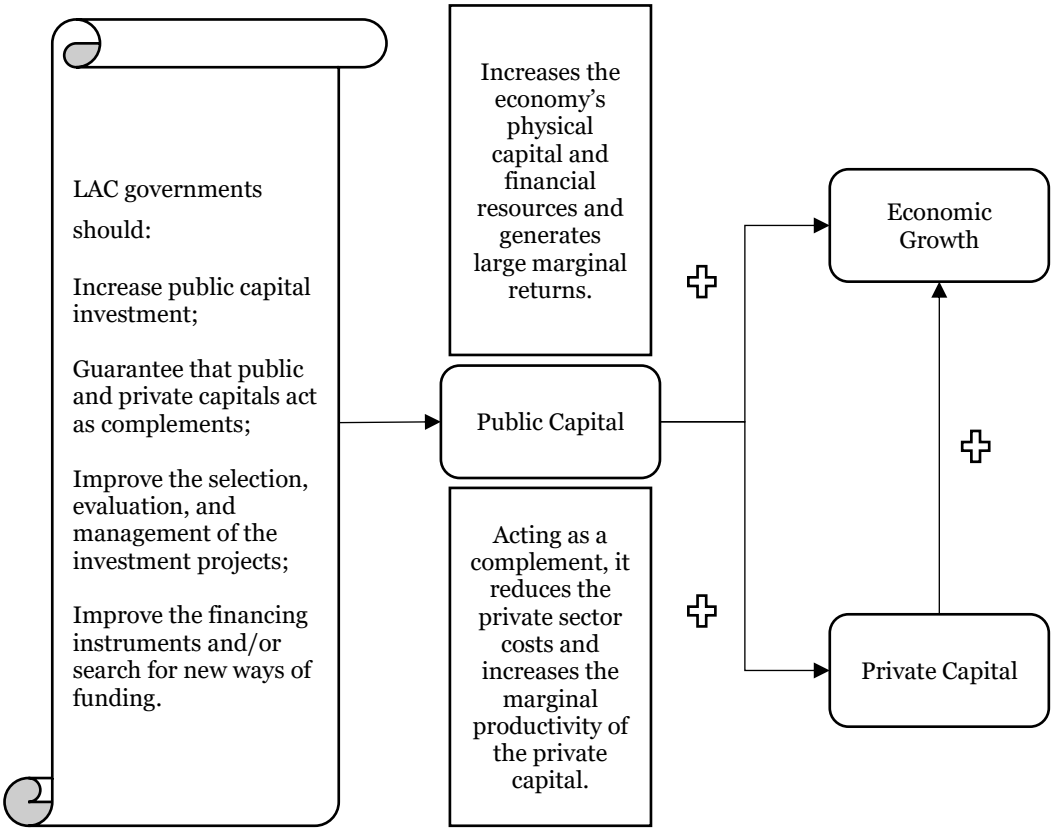

Figure 6.1 – Main conclusions of Chapter 3

Although economic growth can be an indicator that shows if a country/region is on the right development path, being a tool that can be used to achieve various macroeconomic objectives, there are more standards that the countries/regions need to attain in order to consider them as developed ones. In the LAC countries case, there is the problem related to their high inequality levels that could prevent this region from entering on the desirable development path.

Thus, after the analysis of the relationship between the LAC capital stock and economic growth, the impacts that the LAC capital stock has had on the region's income inequality were analysed in Chapter 4. This way, it is possible to see if some changes will be needed in these countries' future physical capital investments in order to decrease their income inequality levels and promote more inclusive development in this region.

To conduct the empirical analysis of Chapter 4, annual frequency data on the Gini index of disposable income (the measure of income inequality), general government capital stock (or public capital stock), and private capital stock was collected for 18 LAC countries from 1995 to 2017. In addition to these variables, which represent the dependent variable and the interest variables, respectively, it was also collected annual frequency data for the following control variables: gross domestic product (GDP); human development index; trade; tax revenue; and unemployment rate. Furthermore, the variable consumer prices index was collected to convert the capital stock variables and the gross domestic product into real/constant values.

The econometric analysis of this chapter was based on the panel autoregressive distributed lag (PARDL) model in the form of an unrestricted error correction model (UECM). The choice of this methodology was based on the following PARDL advantages: it allows to identify the short- and long-run impacts of the variables; it deals appropriately with cointegration; it allows the inclusion of I(0), I(1), and fractionally integrated variables in the same estimation; it is robust when there are signals of endogeneity; and it is capable of giving consistent results with a small/moderate number of observations.

It is also important to stress that three different PARDL models were estimated in the empirical analysis of this chapter: Model I with total capital stock as the interest variable; Model II with the general government capital stock/public capital stock as the interest variable; and Model III with private capital stock as the interest variable. The variable capital stock or total capital stock was achieved through the sum of both types of capital (public and private).

Following the outcomes from the several preliminary tests and specification tests that were computed, the Driscoll and Kraay (DK) estimator with fixed effects (FE) was used to estimate the three PARDL models. After the first estimation of the three models, the variables that did not produce any statistically significant coefficients were removed from the estimation, following the rule of parsimony. The removed variables were the human development index, trade and tax revenue in the short-run in all three models and the total capital stock, public capital stock, and private capital stock in the long-run in Model I, II, and III, respectively.

After the estimation of the parsimonious versions of the models, it should not be ignored the possible existence of shocks that could influence their results. In this sense, the robustness of their outcomes was tested through the inclusion of a set of dummy variables in the three models to control for the identified shocks.

Looking at the results from the parsimonious and non-parsimonious versions of the PARDL models, they were clear in showing that capital stock (either total, public or private) seems to have contributed to enhancing income inequality in these countries in the short-run. A result that holds when the models were corrected for the effects from the shocks (when a set of dummy variables were included in the models). However, in the long run, none of the capital stock variables showed a statistically significant effect on income inequality.

According to the previous outcomes, it seems that there is a necessity that the LAC governments rethink their physical capital investment strategies. It seems that the physical capital investments were mostly made in the already more developed/richer areas, consequently contributing to the increase of these countries' income inequality levels. If the LAC governments continue to ignore the areas where physical capital investments are truly necessary (i.e. the poorest/undeveloped areas) and continue to not create incentives for the private initiative to invest in these same areas, the LAC countries cohesion in terms of income will continue to be difficult to achieve, and their income distribution gap will continue to widen.

It is also important to stress that although the negative impact from capital stock on income inequality seems to have vanished in the long-run, probably due to the efforts that were made to tackle this situation, it does not mean that it does not continue to be necessary to rethink these investments. In fact, the lack of a statistically significant positive impact continues to show that the investment still does not seem to be sufficient to produce the desired reducing effect on income inequality.

In general, it seems that there is still the necessity to improve the selection criteria of the public investment projects in order to develop the poorest/rural areas with a more long-term planned and territorially balanced perspective. Fundamentally, it is essential that the LAC governments continue to increase the physical capital investment levels in the areas where physical capital is scarce.

However, this strategy should be accompanied by the improvement of the physical capital investment projects quality. This not only concerning their implementation but also regarding their preparation and structuration. In addition to contribute to the public investment being more efficient, this could also increase the interest of private partners in financing several investment projects.

In cases where governments face major public investment constraints, the development of public-private partnership (PPP) schemes can be an alternative. However, these schemes should be intensively examined/discussed in order to guarantee that the low-income layers of the population will not be neglected. As in the previous case, a schematic of the main conclusions of Chapter 4 is shown in Figure 6.2.

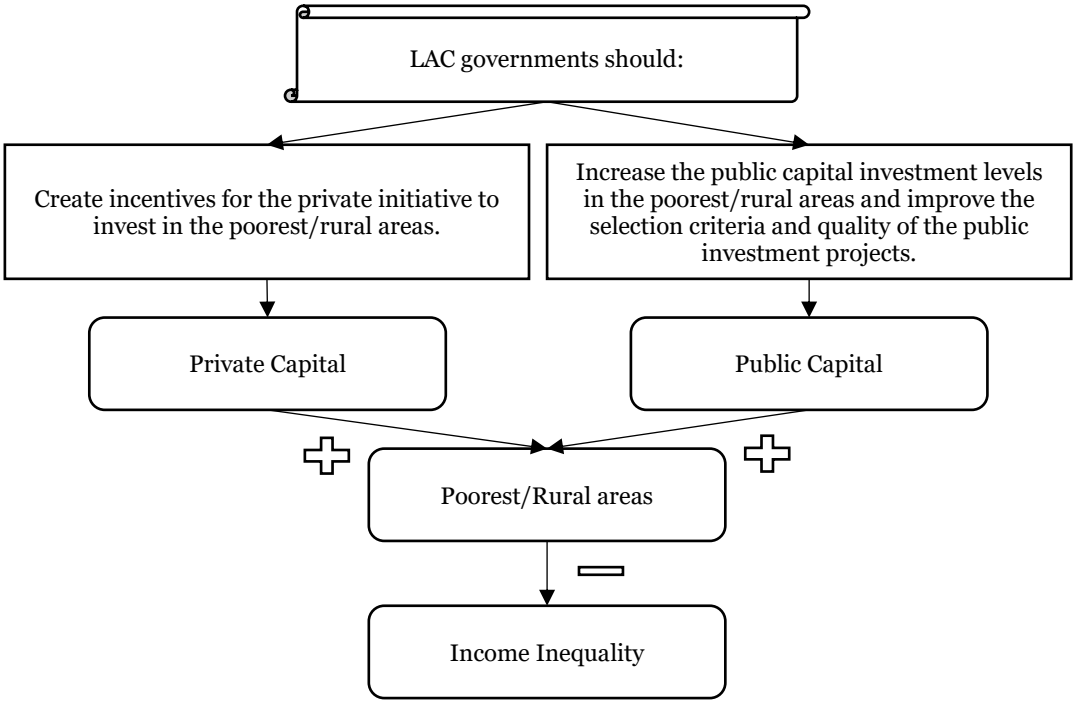

Figure 6.2 – Main conclusions of Chapter 4

After the analysis of the effects of the LAC capital stock on the region's growth (Chapter 3) and income inequality (Chapter 4), in Chapter 5, the analysis was focused on the assessment of the effects that the LAC capital stock has had on the region's energy

intensity. Through this analysis, it was possible to understand whether more energy-efficient physical capital investments are needed in the LAC region and to give several suggestions concerning the future regional physical capital investments so that they could be directed towards the sustainable development of this region.

To accomplish the empirical analysis of Chapter 5, annual frequency data on the gross domestic product (GDP), primary energy consumption, general government capital stock (or public capital stock), and private capital stock was collected for 21 LAC countries from 1970 to 2014. To achieve the model's dependent variable (i.e. energy intensity), it was necessary to compute the ratio between the LAC countries' primary energy consumption and their respective gross domestic product.

It is also important to stress that annual frequency data on CO2 emissions and energy (commodities) prices was also collected in order to include these variables in the model as control variables. Additionally, it should be referred that the variable gross domestic product per capita was also computed (recurring to data on gross domestic product and population) to this same end.

Similarly to the empirical analysis from the previous chapter (Chapter 4), a PARDL model in the form of a UECM was used in the empirical analysis of Chapter 5 in order to investigate the impacts of public capital stock and private capital stock on the LAC countries energy intensity. Again, the choice to use this model was based on the following facts: it allows decomposing the total effects of the variables into their short- and long-run components; it is suitable to deal with cointegration and with the presence of endogeneity; and it permits the inclusion of I(0), I(1), and fractionally integrated variables in the same estimation.

However, in this chapter, the analysis was extended after the PARDL estimation. Indeed, after the PARDL, it was used an approach based on the log t-test to test the converge of the LAC countries in terms of energy intensity and to investigate the possible existence of convergence clubs. Furthermore, an ordered-logit regression model was also used to test the influence of the private capital stock and public capital stock on the formation of the convergence clubs.

After conducting a battery of preliminary tests and specification tests, their outcomes pointed once again to the DK estimator with FE as the most suitable option for the estimation of the PARDL model. After a first estimation (non-parsimonious version of the PARDL), the variables public capital stock, private capital stock and CO2 emissions

per capita were removed from the short-run, as also the variable gross domestic product per capita in the long run, due to the fact that none of them presented a statistically significant effect in the dependent variable.

Looking at the outcomes from both non-parsimonious and parsimonious specifications, they point to a similar conclusion: both public and private capital stocks have had an enhancing effect on the LAC countries' long-run energy intensity. The explanation for this effect to be mainly captured in the long-run can probably be associated with the fact that the LAC economic acceleration was not accompanied by a suitable investment in physical capital. Due to this fact, the effect of the outdated capital (and the lack of new investment) on the region's energy intensity became more and more significant over time.

Overall, the previous results seem to indicate that there is, in fact, a lack of investment in newer and more energy-efficient physical capital in the LAC. It seems that the physical capital from this region proves to be still very energy-intensive. In this sense, there seems to be a need to upgrade the LAC physical capital in both the public and private sectors, from equipment to infrastructure.

Then, through the log-t regression test, it was investigated the hypothesis that the countries in the sample converge to the same steady-state equilibrium in terms of energy intensity. The result from this test indicated that this hypothesis should be rejected, meaning that the sample of LAC countries does not converge to the same steady-state equilibrium.

Through the club clustering algorithm, it was possible to identify four convergence clubs and one divergent group within the sample of countries. These clubs were: "Club 1" composed by Haiti and Honduras; "Club 2" composed of Argentina, Bolivia, Brazil, Guatemala, Nicaragua, Paraguay, Uruguay and Venezuela; "Club 3" composed by Barbados, Chile, Costa Rica, El Salvador, Grenada, Mexico and Peru; "Club 4" composed by Ecuador and Panama; and the "divergent group" composed by Colombia and the Dominican Republic.

Due to the fact that the clubs were ordered by their energy intensity levels ("Club 1" is the most energy-intensive and the "Club 4" is the least energy-intensive.) and to the analysis of their average energy intensity transition paths, it was possible to take some interesting conclusions regarding these countries energy intensity reducing efforts. Indeed, it was

concluded that the countries in "Club 1" and "Club 2" are probably the ones that need to make an additional effort to reduce their energy intensity level.

Although the importance of the previous analysis and its subsequent inferences, one of the main objectives of the convergence analysis was to identify the LAC convergence clubs in order to be able to construct an ordinal response variable. Then, the idea was to use this variable in an ordered logit regression model to investigate if the public and private capital stocks were determinant factors for the formation of the energy intensity convergence clubs in the LAC. In other words, to see if capital stocks were capable of decrease/increase the probability of a country belonging to a low/high energy intensity club.

Following the results from the ordered logit regression model, neither the public capital stock nor the private capital stock seems to be determinants for the convergence clubs formation. This outcome seems to indicate that the effects of both public and private capital on energy intensity are similar in most of the LAC countries, with the difference of these clubs, in terms of energy intensity, coming from other factors. Overall, it seems that the conclusion from the ordered logit regression model shows that the PARDL assumption that newer and more energy-efficient capital is needed in the LAC can be extended to all countries, regardless of which club they are in.

In general, from the outcomes of the empirical investigation conducted in Chapter 5, it was concluded that despite the decreasing trend on the LAC region energy intensity level, neither public nor private capital contributed to this tendency. In fact, they seem to have contributed to preventing the region from reaching even lower energy intensity levels, with both types of capital showing to have had an enhancing effect on the long-run energy intensity of the LAC countries.

Due to the previous outcome, it would be wise (even imperative) that the governments from the LAC region increased their investment in new and more energy-efficient physical capital. They should channel a large part of their investment efforts to increase the energy efficiency of their countries' infrastructures, machines and equipment (with particular attention to the case of the most energy-intensive economic sectors).

Nevertheless, due to the region's low degree of maintenance of the existing physical capital, it could be appropriate to promote energy audits to the existing capital. This because, sometimes, it could be more pertinent to invest in the maintenance and upgrade of the existing capital than to invest in new physical capital. Moreover, in order to be able

to carry out this investment in a sustainable manner, the LAC governments should improve their public financing instruments as also the quality of their public investment projects to, if necessary, be able to call upon institutional investors.

As expected, the increase in these countries' investment levels must be accompanied by the creation and/or the improvement of their energy efficiency laws/regulatory framework. Nevertheless, as it is not just the public capital that needs to improve its energy efficiency, the LAC governments should make an effort to create measures and incentives in order to promote the improvement of energy efficiency in the private sector.

Finally, given the importance of this issue to the LAC energy transition plan, the strategies to promote greater energy efficiency in the LAC countries should be more significantly present on the agendas of regional organisations. Moreover, it is also essential that these strategies be discussed in a more concerted way so that it is possible to create a more homogeneous energy efficiency promotion plan for the LAC region. As in the previous cases, the main conclusions from Chapter 5 are presented in Figure 6.3.

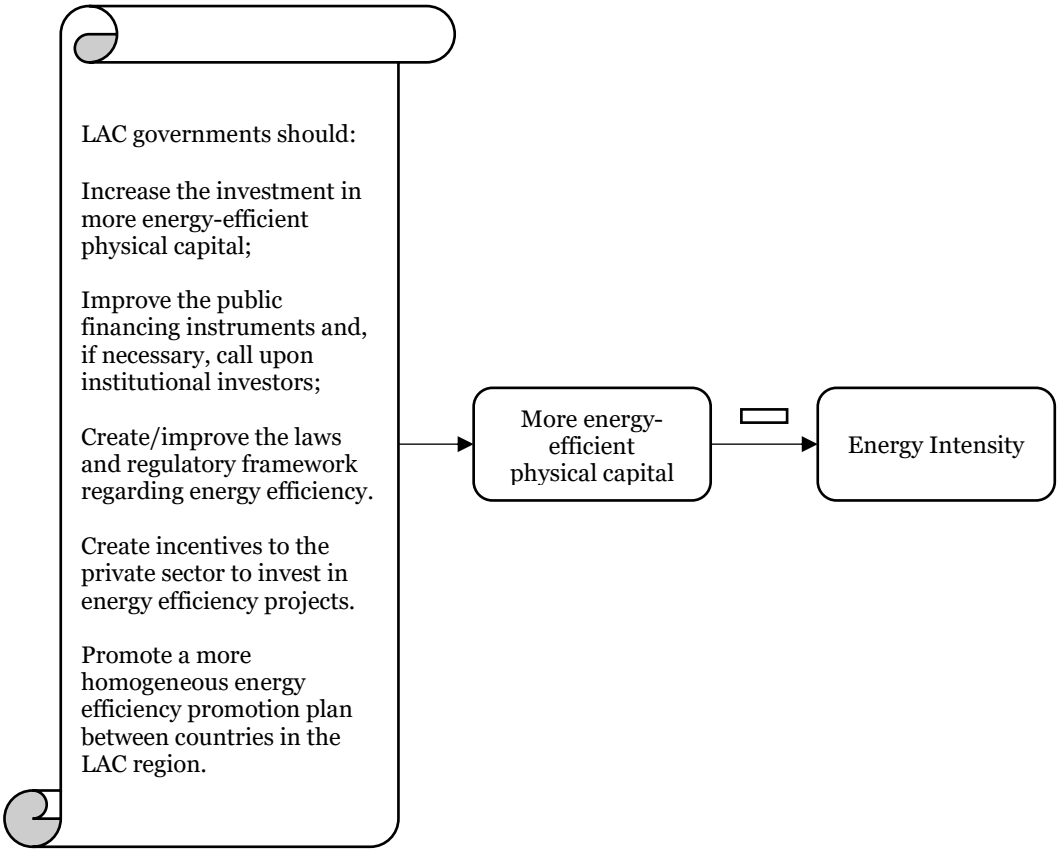

Figure 6.3 – Main conclusions of Chapter 5

After reviewing the chapters of this thesis and presenting their respective conclusions and policy implications, it is now possible to answer the question, “Is the Latin American and Caribbean capital stock affecting the development of the region?”. From the results of the estimations, it seems that it is and that some changes are needed in this countries’ physical capital investment strategies so that they will be able to promote the economic growth and the inclusive and sustainable development of this region.

In sum, for the LAC to achieve a higher development level, the region’s governments should increase their public investment levels, namely the one channelised to infrastructure development. At the same time, they should improve the conditions to attract and maintain private investment in this region. This because both types of capital seem to have positive effects on their long-run economic growth.

Nevertheless, to guarantee that these countries did not end up in situations where public capital investment hampers their growth, it is necessary that the LAC governments weigh their fiscal space in order to ensure that no negative fiscal costs will be associated with their investments. In addition, it is also necessary to create the conditions to that public and private capital act as complements and not as substitutes.

Moreover, to reduce the LAC countries' income inequality levels, there is a need for a significant part of this region's future physical capital investments to be channelised to the most impoverished/undeveloped areas. Contrariwise, if physical capital investments are almost exclusively channelled to the already richer/developed areas, the income gap in these countries will continue to increase.

Finally, due to the enhancing effect that both public and private capital seem to have had on the region’s energy intensity, the future LAC physical capital investments should also be focused on improving the region's energy efficiency and the decrease of its energy intensity. Thus, there is the need to invest in new and more energy-efficient physical capital, as also to invest in the upgrade of the existing capital. This should be done in the public and private sectors, with special attention to the most energy-intensive sectors of the LAC economies.

6.2 Limitations and Future Research

Before concluding this chapter, it is important to mention some of the difficulties that were faced during the research as also to give some suggestions for future research in this thematic. Due to the data availability, it was not possible to use the same panel of countries in all the empirical estimations as was initially intended. Due to the lack of

data, it was necessary to remove several countries (and years) from the estimation in some cases. This was especially noticeable in the analysis of the effects of capital stock on income inequality. Although the results and the subsequent conclusions from the estimation can still be applied to the generality of the LAC countries, it should be referred that the lack of income inequality data for this region still creates some constraints to the deepening of the study on the inequality issue in the LAC.

Moreover, it is also important to stress that the conclusions regarding the effect of capital stock on income inequality could be more deeply analysed if there were income inequality data for the rural and urban subsamples. Indeed, although the Gini Index from the CEPALSTAT makes this division, for now, this database holds an unbearable number of blanks which, as expected, makes the use of such data unviable. Hence, when this (or another) database allows it, it can be interesting to analyse the effect of capital stock on income inequality making the division between the rural and urban areas.

Given the importance and the predominance of the public-private partnerships (PPPs) in the LAC region, it could also be suitable to analyse its effects on the regions' development. More properly, it could be interesting to empirically check if this type of investment schemes, which involve the collaboration between governments and private-sector companies, can contribute to promoting the growth, equality and energy efficiency of this region.

Unfortunately, at the time when this empirical research was being developed, the data on PPP capital stock from the IMF was still very incomplete, especially when compared to the public and private capital stock data. Thus, when the data allows it, it would be interesting to extend the analysis to the effects of PPP capital stock on the region's development.

Finally, in future research, it could also be important to evaluate the role of some additional features which could affect the success and efficiency of the physical capital investment, namely the one on infrastructure assets. Some examples of these features can be, for example, the role that the LAC countries' regulation frameworks and their respective regulatory agencies have on the provision of physical capital in this region.