LUND UNIVERSITY
School of Economics and Management

Master's Programme in Economic Development and Growth

The Link between Economic Complexity, Natural Resource Abundance and Economic Development - Empirical Evidence from Latin America

by

Julian Gäng

julian.gaeng@gmx.de

Abstract: After 30 years of empirical research on the effect of natural resource abundance (NRA) on economic development, the literature identified several preconditions for an economy with NRA to experience slow economic growth. More recently, the measure of Economic Complexity (ECI) has been introduced. The measure aims at capturing the amount of productive capabilities an economy has obtained and it is found to be highly predictive for long-term economic growth. Yet, few have empirically tested the link between NRA, ECI and long-term economic growth. This thesis investigates (1) the yet missing theoretical link of why ECI could be preconditional for an economy's growth experience depending on its degree of NRA and (2) first empirical evidence of this link for Latin American countries. Using a cross-sectional empirical approach, I find that for Latin American countries (N=20) the effect of NRA on long-term economic growth (1995-2019) remains negative, even if conditioned on ECI.

Keywords: Economic Complexity, ECI, Productive Capabilities, Natural Resource Curse, Path Dependence, Conditional Economic Growth, Diversification

Course code: EKHS42
Master's Thesis (15 credits ECTS)
December 2023
Supervisor: Martin Andersson
Examiner: Tobias Karlsson
Word Count: 12752

Acknowledgements

I want to thank Martin Andersson for inspiring and promoting discussions.

Tambien, te agradezco. Gracias a ti me veo feliz.

Ich möchte meiner Familie danken. Dafür, dass ihr mich während des Arbeitsprozesses immer aktiv unterstützt habt, aber insbesondere dafür, dass ihr einfach für mich da seid.

Table of Contents

1 Introduction 1

1.1 Evolution of the *Natural Resource Curse* and the emergence of Economic Complexity 1

1.2 Research Problem and Aim of Scope 6

1.3 Outline of the thesis 7

2 Theory and previous research 9

2.1 The idea behind Economic Complexity 9

2.2 Computation of Economic Complexity (ECI) and Product Complexity (PCI) 10

2.3 Distinction between Economic Complexity and GDP per capita 14

2.4 *Productive Knowledge* - A theoretical framework behind Economic Complexity .. 17

2.5 Natural Resource Curse mechanisms 22

2.5.1 Institutional resource curse explanations 22

2.5.2 Market-based resource curse explanations 23

2.6 How does Economic Complexity evolve? 26

2.7 The case of Latin America 29

2.8 Effect of NRA on Economic Complexity: Reviewing Avom et al. (2022) 32

2.9 Quiescene 33

2.10 Economic Complexity and Diversification 33

2.11 The link between NRA and Institutional Quality 35

2.12 Strategies to empirically test the NRC 35

3 Data 37

4 Method (empirical approach) 41

5 Empirical results and discussion 42

6 Conclusion 46

References 47

Appendix A 51

1 Introduction

1.1 Evolution of the *Natural Resource Curse* and the emergence of Economic Complexity

The so-called *Natural Resource Curse* (NRC) describes the empirical finding that since the 1970`s countries with large natural resource wealth tend to have experienced slow economic growth. This finding seems paradox, as we expect (according to neoclassical theory) that countries with large natural resource wealth use this additional, "free" income to speed-up growth.[1]

Sachs and Warner (1995) were the first to have empirically shown a negative relationship between long-term growth and resource wealth.[2] The authors explain the underperformance with the effects resource booms have on the manufacturing sector as the resulting inflation and movement of labor and capital weakens the competitiveness of the manufacturing (exporting) sector (the so-called Dutch disease explanation). Implicitly, it is assumed that the booms are of a short-lived nature and that manufacturing activities are desirable for long-term economic growth. (Corden and Neary (1982))

Thereupon, a large body of research followed. While one strand of literature is testing alternative explanations (channels) of how resource wealth might affect economic development, another strand has identified certain *contingencies,* as countries are not unconditionally cursed when endowed with plenty of natural resources (for example, Norway and Botswana have experienced fast growth in the recent past). (Lashitew and Werker (2020),

---

[1] "After all, natural resources raise the wealth and the purchasing power over imports, so that resource abundance might be expected to raise an economy´s investment and growth rates as well." (Sachs and Warner (1995), p. 2-3)

[2] Sachs and Warner (1995) use a global sample in a cross-sectional OLS setup where the dependent variable is average real GDP per capita growth between 1971 and 1989 and natural resource wealth is measured by the share of fuel exports in GDP.

p.2) For example, not all types of natural resources[3] are found to be (equally) harmful. Especially petroleum is found to be potentially harmful for economic development. (Frankel (2010); Badeeb et al. (2017))

The level of *institutional quality* in the economy is an important contingency. As one of the first, Mehlum et al. (2006) show that the long-term growth performance of resource rich countries depends on the initial level of institutional quality. Specifically, the authors show that resource rich countries with low initial institutional quality have experienced slow growth while resource rich countries with sufficient institutional quality at the beginning of observation exhibit average long term growth rates. This suggests that the level of institutional quality *"[...] determines the extent to which resource revenues are put to effective use for advancing developmental outcomes."* (Lashitew and Werker (2020), p. 1)

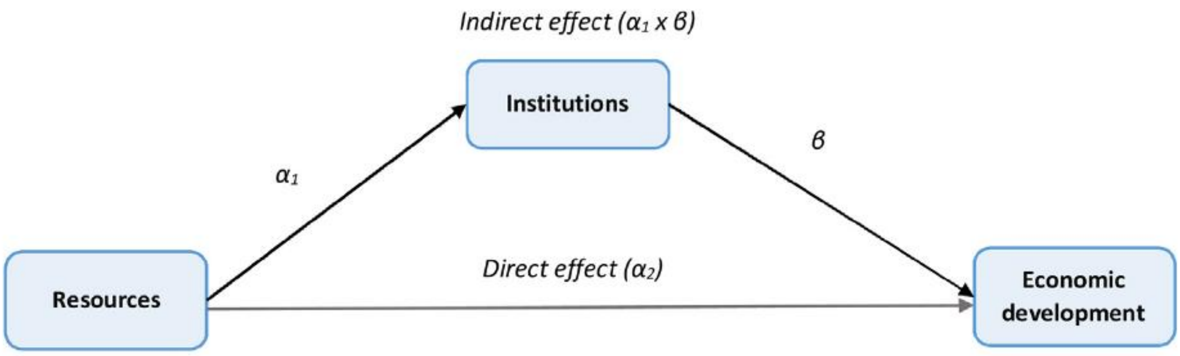
Research in the field of political science can give more insights: Petroleum wealth is found to notably increase corruption, violent conflicts and the chance of authoritarian regimes to persist. (Ross (2015), p. 240) Evidently, a deterioration of institutional quality due to natural resource wealth in turn affects the economic performance as institutions are fundamental for economic development. (North (1994), Frankel (2010), p. 15)

In conclusion, natural resource wealth can negatively affect economic growth in two ways as shown in figure 1 below: Directly, e.g. through the Dutch disease mechanism and indirectly through institutions. (Lashitew and Werker (2020), p. 2) Similiarly, Gylfason (2001) provides evidence that public expenditure (relative to GNP) for education tends to be lower in resource rich countries. A lower educational level in turn affects economic outcomes.

---

[3] Natural resources are natural assets which can be used in the value adding process such as minerals, natural gas, oil, trees, water, wind and fertile land.

Figure 1: The direct and indirect effect of natural resource wealth on economic development



Source: Extracted from Lashitew and Werker (2020), p. 2

Even though today we understand more of how natural resource wealth affects economic development, there is still contradictory evidence leaving the NRC puzzle unresolved. (Badeeb et al. (2017), p. 1) One reason for these contradictions is the multiplicity of possible channels affecting economic development through natural resource abundance, as it is a major difficulty in empirical testing to effectively control for these. (Lashitew et al. (2021), p. 169)

More recently, located within the field of economic development, the concept of Economic Complexity has emerged. By definition, Economic Complexity captures the amount of productive capability a society has accumulated. (Hausmann et al. (2014), p. 18) Since first mentioned in Hidalgo and Hausmann (2009), Economic Complexity and its Index have received a lot of attention from different directions of research. However, Economic complexity is still a relatively new field of research. (Hidalgo (2021), p. 93))

Since 2020 several authors have introduced the Economic Complexity Index (ECI) into the empirical research on natural resource abundance and its effect on economic development. Overall, in their empirical models, the ECI – additionally to some measure of natural resource abundance - is introduced in two ways: Either in ”traditional” growth regressions as an *intermediate-term* (Gräbner et al. (2020), Mesagan and Vo (2023) and Tabash et al. (2022)), as it has been done with institutional quality (e.g. Mehlum et al. (2006)) or as the dependent variable (Avom et al. (2022)), where it is tested if Economic Complexity itself is affected by changes in natural resource abundance. Overall, the authors find significant results confirming the Natural Resource Curse (NRC) and the role of Economic Complexity as an intermediate term.

Table 1: Overview of the literature investigating the effect of Economic Complexity and Natural Resource Abundance (NRA) on long-term economic growth

Author & year	**Empirical approach**	**Finding**	**Incentivization**
Mesagan and Vo (2023)	(Endogenous) resource growth model with ECI and natural resource abundance (NRA) as intermediate variable. Panel analysis: VECM with Pool Mean Group (PMG) framework. 28 African countries, 1995-2019	Short-term effects: NRA (authors use natural resource rents as a ratio of GDP p.c.) on growth (GDP p.c.): positive but insignificant (and shrinks in the long-term). ECI on growth (..): negatively (!) and significantly. NRA*ECI on growth: positive but insignificantly Long-term effects: NRA on growth: positive but insignificant. ECI on growth: positive and significant. NRA*ECI on growth: Positive and significant.	*"What can explain ECI's negative short-run effect on growth?"*
Tabash et al. (2022)	(Exogenous) resource growth model with ECI and natural resource abundance (NRA) as intermediate variable. Cross-country analysis: System GMM, (tackles endogeneity issues but only takes immediate effects into account) 24 African countries, 1995-2017.	The effect of NRA (authors use natural resource rents as a ratio of GDP p.c.) on GDP p.c. growth (1 year) is negative and significant. The effect of ECI on GDP p.c. is positive and significant. The effect of the intermediate variable ECI*NRA on GDP p.c. growth is positive and significant.	The finding of the positive effect of the intermediate variable on growth is *"[…].implying that high Economic Complexity enhances the efficiency of natural resources and thus positively impinges upon economic growth."* The authors confuse ECI with being a measure of diversification: *"A higher economic complexity index implies a more complex and diversified economy […]"* (p. 2)

Gräbner et al. (2020)	Pooled OLS à la Sachs and Warner (1995). Long-term average growth rate (30 years) as dependent variable. 108 countries (data availability), 1985-2014. The authors actually investigate whether (economic growth-) convergence is conditional on technological capability (proxied by ECI). The authors thereby control for NRA – a possible contingency of conditional convergence (another popular contingency is institutional quality). See table 3 for the empirical results.	The effect of NRA (the authors use the share of oil or metals and coal exports in the total export; a measure of natural resource dependency => later more on this) on long-term growth rates while controlling for ECI is weakly positive and insignificant. General finding: Convergence (30 years) is conditional on technological capability (i.e. initial GDP pc level only becomes significantly negative when it is controlled for initial ECI-level).	Inconclusive results (regard. NRA on long-term economic growth) when using a global sample. Economic Complexity – as well as Institutional Quality - is conditioning convergence – what's the difference between them? Common candidates conditioning convergence: Institutions, natural resource abundance, geography, economic openness, Economic Complexity. The authors use the ECI as a proxy for technological capability for the first time – is this valid?

Table 2: Overview of the literature investigating the effect of Natural Resource Abundance (NRA) on Economic Complexity.

Author & year	**Empirical approach**	**Finding**	**Incentivization**
Avom et al. (2022)	Investigate the effect of NRA on ECI. Pooled OLS and system GMM. 108 countries, 1995-2017	"NRA has a negative effect on ECI."	The paper at hand criticizes the empirical strategy of Avom et al. (2022) at the end of chapter 2. To understand the critique, pay attention to how the ECI is computed (especially to the nomination of a product being considered in the computation of the ECI: the Revealed Comparative Advantage (RCA) by Balassa).

Essentially, the joint finding of this recent work suggests that Economic Complexity functions in a similar way - in terms of channeling - as institutional quality does: The level of Economic Complexity is conditioning whether Natural Resource Abundance becomes beneficial or detrimental for an economy. Furthermore, Avom et al. (20) also shows evidence that Economic Complexity itself is affected by NRA.

1.2 Research Problem and Aim of Scope

- So far, the parallels between Economic Complexity and Institutions haven´t been discussed within the context of the NRC literature: Are these presumed similarities expected? What are the differences? Is Economic Complexity a more suited measure to predict if a country is undergoing the Natural Resource Curse?

- Evidence on the intermediating relationship of Economic Complexity (ECI) and Natural Resource Abundance (NRA) is rather scarce and only exists for African countries. Does the intermediating role of ECI and NRA within growth equations also apply for Latin American countries; the other world region presumably negatively affected by the abundance of natural resources?

- Furthermore, we review the finding of Avom et al. (2022) who find that Economic Complexity itself is affected by Natural Resource Abundance. This finding is not surprising considering the amount of literature suggesting that institutional quality itself is affected by NRA (however, there is also . However, we find severe errors of model misspecification within the work of Avom et al. (2022). What can be done to correctly specify the empirical model to test if Natural Resource Abundance affects Economic Complexity?

Respectively, the prospect and contribution of this paper is as follows:

A) We shed light on the relationship between Economic Complexity and Institutional Quality and try to answer why (or why not) both indicators function in a similar way and what are the differences. We therefore introduce popular NRC mechanisms and reflect these upon the theory on Economic Complexity. We suggest how NRA and Economic Complexity can be linked.

B) Following Gräbner et al. (2020), Mesagan and Vo (2023) and Tabash et al. (2022) we empirically test if the intermediating relationship between Economic Complexity and Institutional Quality also holds for the Latin American continent.

C) We give insight as to why the empirical model of Avom et al. (2022) is misleading and thus need to reevaluate the joint finding of the pertinent research. Furthermore, considering future research, we suggest an alternative to empirical test the relationship between EC and NRA.

Eventually, prospect A) and B) will be concluded in section 6. Clarification and discussion of prospect C) can be found in chapter 2.8.

1.3 Outline of the thesis

In this work, the general approach follows the goal of familiarizing the reader peu à peu with the knowledge from research to understand and motivate the design of the empirical model and the interpretation of its results. Specifically, as it is our goal to shed more light onto the relation between Economic Complexity and Institutional Quality within the empirical framework of the NRC, it is crucial to fully understand the theory behind the new concept of Economic Complexity.

Hence, chapter 2 will mostly evolve around Economic Complexity: Upon introducing thoughts towards Economic Complexity in (2.1) it follows that we show in (2.2) how the ECI is computed. In (2.3) we will deepen the understanding of Economic Complexity by comparing it to the seemingly familiar measure of GDP per capita. It follows the introduction of the underlying theoretic model of Economic Complexity in (2.4). With this theoretical knowledge in mind, we reflect upon the NRC theory of the different mechanisms (2.5). We will see that there is an immediate link between Economic Complexity theory and NRC mechanisms. The so-called *Product Space* (2.6) eventually gives empirical evidence on previously debated NRC mechanisms. Finally, we oversee characteristics of the Latin American region in respect to their NRA and institutions in (2.7). Before we proceed towards the empirical investigation, we explain in (2.8) why the empirical approach of Avom et al. (2022) is not valid and propose a way to control for the endogeneity issue.

From chapter 2.9 on, we focus on the direction of NRA affecting economic long-term growth, conditioned by the level of Economic Complexity or of institutional quality. We therefore report different empirical findings from the literature which need to be considered for our empirical model and the interpretation of the results.

Chapter 3 presents the data used. Chapter 4 introduces our empirical approach and motivates again our investigation and goals (see 1.2). In chapter 5 we report and discuss the results before we conclude the work in chapter 6.

2 Theory and previous research

2.1 The idea behind Economic Complexity

Economic Complexity aims to capture the amount of *productive capability* an economy possesses. First mentioned in Hidalgo and Hausmann (2009), the basic underlying assumption behind the concept is that the products an economy produces *reflect* the amount of productive capability the economy holds and that a substantial part of these capabilities is not tradable and thus causes differences in productivity and income between countries. (Hidalgo and Hausmann (2009))

The authors suggest thinking about productive capabilities as Lego pieces (so every country possesses a different collection of Lego pieces). Accordingly, the production of some goods requires more Lego´s than other (less complex) goods, some goods require very specific Lego pieces and moreover, some goods require Lego pieces which are not tradable such as ”property rights, regulation, infrastructure and labor skills” (Hidalgo and Hausmann (2009), p. 10570).

Indeed, Economic Complexity uses export data in order to capture the products an economy produces (and exports) and so its different productive capabilities (different lego pieces) required to produce that good and thus necessarily held by that country. To quantify the amount of productive capability held by that country, Hidalgo and Hausmann (2009) make use of the two economic ideas – complexity and connectedness – and, using export data, implement these ideas through network methods and dimension reduction technique to compute the Economic Complexity Index (ECI). Thus, the ECI indicates how complex the economy is, or in other words, how many productive capabilities the country possesses. Both the ECI and its underlying ideas complexity and connectedness will be explained in more detail in this chapter.

Overall, the ECI can be seen as a powerful indicator of the level of economic development. Similarly to the traditional neoclassical approach to growth (where growth usually is proxied by GDP per capita), Economic Complexity with its concept of productive capability follows the idea of an input-output driven model of economic performance. However, opposed to the traditional growth approach, Economic Complexity does not need to understand what the different inputs (factors of growth such as physical or human capital) are and how they materialize themself into growth, but instead Economic Complexity receives the output in terms of *complexity* and *relatedness* and in this way estimates the combined and so effective presence of the different inputs. (Hidalgo (2021), p. 92)

Opposed to the traditional approach, *specificity* and *complementarity* of the different growth factors are not neglected. Thus, measuring Economic Complexity provides the amount of productive capability which is effectively put into work (an output-based measure), while trying to capture the different factors of production individually (specificity problem) does not provide all the information of complementarity.

2.2 Computation of Economic Complexity (ECI) and Product Complexity (PCI)

Following Hausmann et al. (2013) and Hidalgo and Hausmann (2009) in this section the computation of the Economic Complexity Index (ECI) will be formally derived. The ECI indicates the amount of productive capability (or Economic Complexity) a country holds, in respect to the rest of the world.

The authors use international trade data (values) and classify the exported products by groups according to the Standard International Trade Classification (SITC) or the COMTRADE Harmonized System (HS) at the 4-digit level.

In the first step, the authors relate each country with each product group. An adjacency matrix M_{cp} is thereby obtained, where rows relate to countries (c) and columns to products (p). It is defined that any element $m_{cp} \in M_{cp}$ gets assigned the value 1 if $RCA_{cp} > 1$ and otherwise 0. Where the Revealed Comparative Advantage (RCA_{cp}, by Balassa) is defined as follows:

$$RCA_{cp} = \left. \frac{x_{cp}}{\sum_c x_{cp}} \middle/ \frac{\sum_p x_{cp}}{\sum_{cp} x_{cp}} \right. \qquad (1)$$

Accordingly, a country c has an $RCA_{cp} > 1$ in product p if the share of p (in $) in country c in the value ($) of the global exports of that same good is larger than the countries *expected share* of exports in that good. The expected share for country c in p is equal to a country’s total exports ($) over global exports ($). Eventually, the RCA_{cp} definition is used to make countries and products comparable. (Hausmann et al. (2013), p. 25)

Consequently, the information obtained from the resulting adjacency matrix M_{cp} then can be interpreted as follows:

The sum of a row of M_{cp} represents the **diversity** of a country's exports (*how many different products can a country export with $RCA_{cp} > 1$*). Formally,

$$\sum_p M_{cp} = k_{c,0} \quad (2)$$

The sum of a column of M_{cp} represents the **ubiquity** of a product (*how many countries can export that product with $RCA_{cp} > 1$*). Formally,

$$\sum_c M_{cp} = k_{p,0} \quad (3)$$

So that $k_{c,0}$ denotes a countries diversity of its exports and $k_{p,0}$ denotes the ubiquity of a product.

Note that the information carried by products (ubiquity) and by countries (diversity) are of an interrelated nature: In order to obtain a precise measure of the finesse and variety of the country's productive capabilities ("the complexity"), we need to know the average ubiquity of exports (with $RCA_{cp} > 1$)– which in turn requires the information about the average diversity of the countries exporting this exact same good. (Hausmann et al. (2013), p. 24)

Consequently, we follow a recursive procedure (Hidalgo and Hausmann (2009) name this the "Method of Reflection") of the following form:

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_p M_{cp} \times k_{p,N-1} \quad (4)$$

$$k_{p,N} = \frac{1}{k_{p,0}} \sum_c M_{cp} \times k_{c,N-1} \quad (5)$$

where both equations are related and average diversity and ubiquity are iteratively, based on the previous (average) level of diversity/ubiquity, calculated. (Hidalgo and Hausmann (2009))

To obtain the ECI, the complexity of a country (and the complexity of products (PCI)) we insert (5) into (4):

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_p M_{cp} \times \frac{1}{k_{p,0}} \sum_{c'} M_{c'p} \times k_{c',N-2} \quad (6)$$

which can be simplified to:

$$k_{c,N} = \sum_{c'} k_{c',N-2} \times \sum \frac{M_{cp} M_{c'p}}{k_{c,0} k_{p,0}} \quad (7)$$

We then get:

$$k_{c,N} = \sum_{c'} k_{c',N-2} \times \widetilde{M}_{cc'} \quad (8)$$

where $\widetilde{M}_{cc'} = \sum_p \frac{M_{cp} M_{c'p}}{k_{c,0} k_{p,0}}$

Equation (8) is satisfied when $k_{c,N} = k_{c,N-2} = 1$, which equates the eigenvector of $\widetilde{M}_{cc'}$. The eigenvector $\vec{K}$ with the second largest eigenvalue (the largest eigenvector is a vector of only 1´s) is chosen and in equilibrium ECI is obtained:

$$\text{ECI} = \frac{\vec{K} - mean(\vec{K})}{std.(\vec{K})} \quad (9)$$

where $\vec{K}$ is normalized with its mean and standard deviation.

Analogously, the PCI is defined as $= \frac{\vec{Q} - mean(\vec{Q})}{std.(\vec{Q})}$ (10)

Finally, note that by this procedure information from 2 dimensions - diversity and ubiquity – is reduced into 1 dimension, which is captured by the ECI (and analogously the PCI). (Hausmann (2021), p. 92)

Both indices are calculated on a yearly basis and, again, they reflect a relative measure as a country's economic complexity is compared to the economic (product) complexity of all other countries (products). The Observatory of Economic Complexity (OEC)[4] reports ECI data for

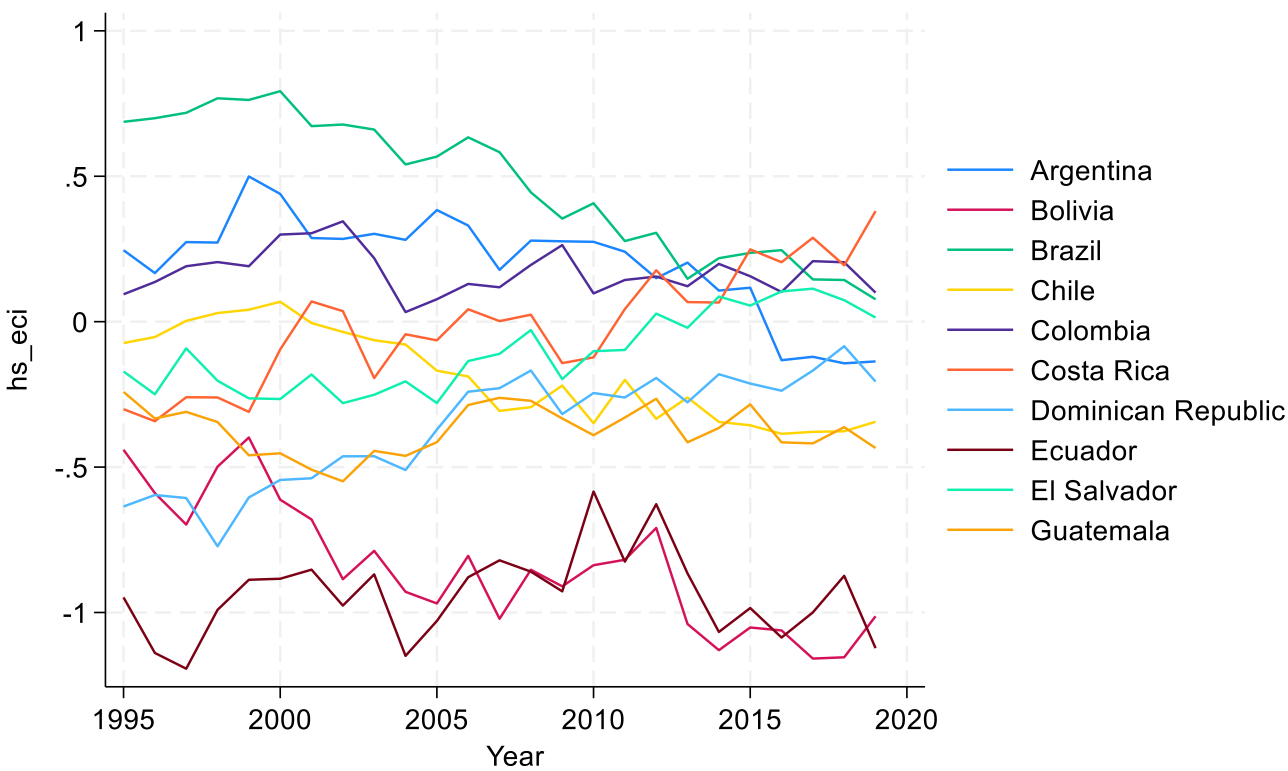
---

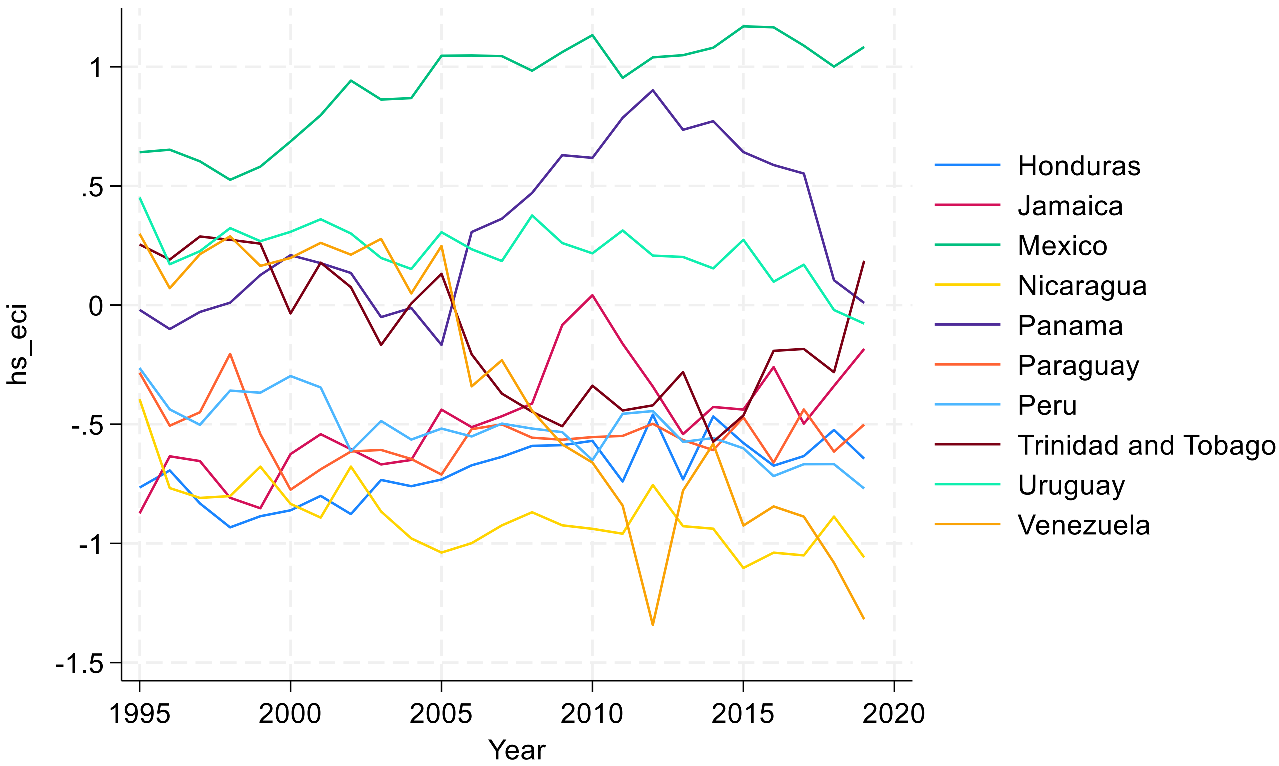
[4] https://oec.world/en/resources/about

128 countries (globally, all countries are considered with available data and population size above 1.2 million). (Hausmann et al. (2013))

So far, globally ECI values were ranging from about -2.5 (very few productive capabilities) to +2.5 (very many productive capabilities; in 2017 the top 3 countries with highest ECI were Japan, Switzerland and Germany, accordingly) and is available for 128 countries from 1962 onwards. Figure 1 below shows the course of ECI´s for Latin American (where data is available) countries from 1995 to 2019:

Figure 1: ECI´s (based on HS data) of Latin America 1995-2019





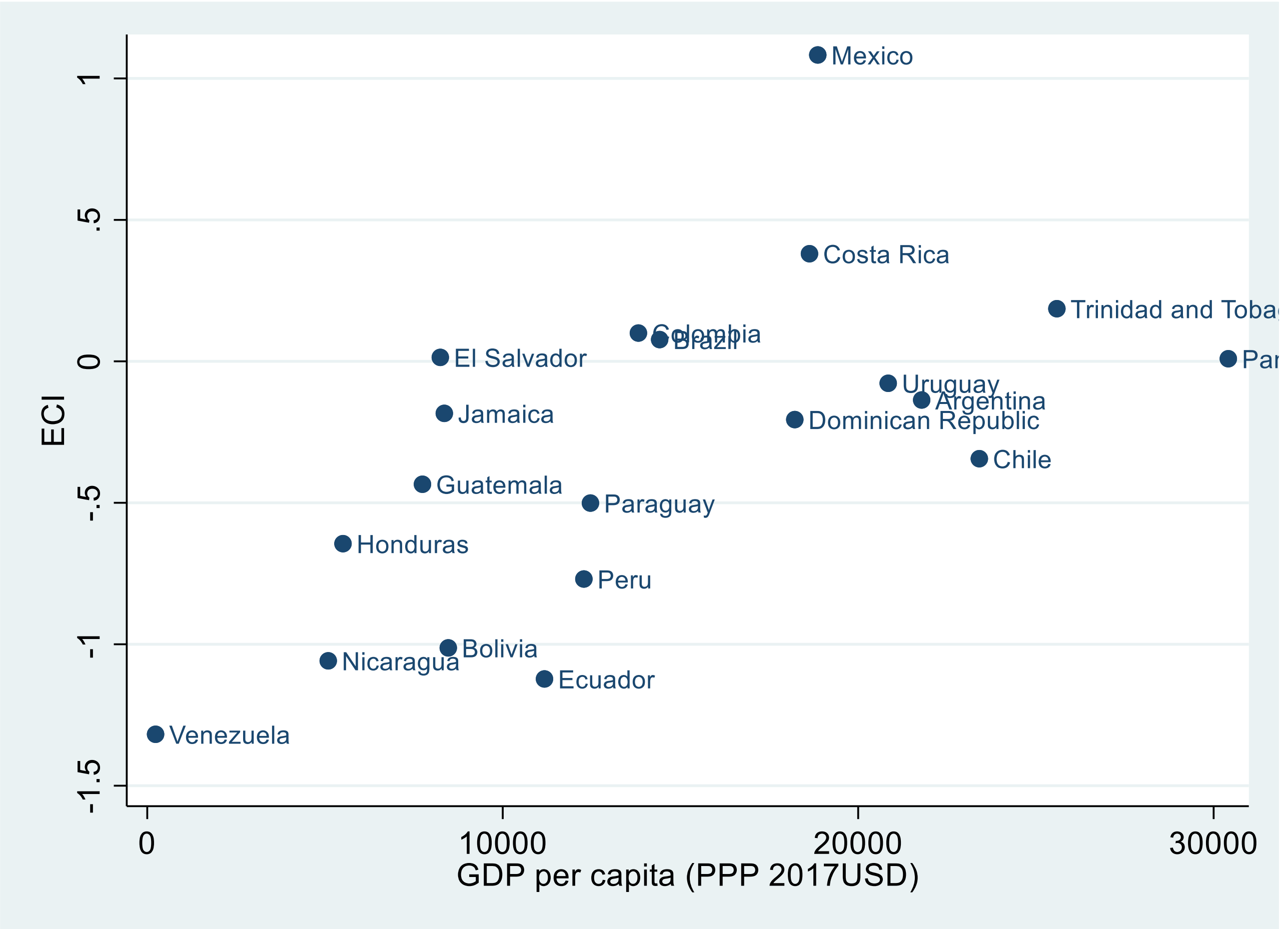
2.3 Distinction between Economic Complexity and GDP per capita

To gain a better understanding of Economic Complexity and to clarify misperceptions previously done in the literature, we will further explicate what Economic Complexity is and what not by confining EC from related measures (GDP per capita and "diversity measures"). We will look into Connectedness, the final building block to understanding why ECI is a superior proxy for economic development. Finally, we will present an underlying theoretic model as an "innovative" approach of how we can think about the economic development and the achievement of Economic Complexity. Then, we will review NRC mechanisms in the light of Economic Complexity: Why should natural resource abundance affect Economic Complexity or why should ECI and NRA function as an intermediator within a growth model?

Deducing from the computation of the ECI, the index gives us information about a country`s capability of producing a variety of sophisticated products. As such, Economic Complexity tells us something about the economic structure while GDP per capita – the traditional measure of economic development and growth - measures the aggregate output of an economy.

Below, figure 2 shows the relationship between income (GDP per capita) and Economic Complexity for the 20 largest Latin American economies in 2019.

Figure 2: Association between GDP per capita and ECI in 2019 Latin America



Source: Own calculation. Note: ECI is based on HS data; GDP per capita is based on the "rgdpna" series of PWT10.01. Included are all Latin American countries with a population size above 1.2 million.

Clearly, both variables are positively correlated and thus, we question if *"Economic Complexity is just another measure of prosperity?"*.[5] In order to confine Economic Complexity from income, it is useful to highlight the ECIs extraordinary high predictability of (future) long-term

---

[5] The Pearson coefficient for GDP p.c. and ECI in 2019 (20 observations) is 0.62. Furthermore, as it may seem that populated countries such as Mexico, Brazil and Colombia have relatively higher ECIs - note that the correlation between ECI and population is weak (0.38) and Hausmann et al. (2013, p. 30) also confirm that population size is not a significant factor in explaining future growth. See appendix A.1 for the corresponding correlation matrix.

income growth. Hausmann et al. (2013) show that the ECI can explain 18% of the variance of a future 12 year growth period, while institutional quality - a common benchmark which here is measured by an aggregated indicator of all 6 Worldwide Governance Indicators (WGI)) – can only explain 3%, accordingly. Intuitively, that means that the countries shown in figure 2 which are laying above a hypothetical fitted line possess more productive capabilities than expected (according to their income level) and will likely experience more than average (based on the initial income level to control for convergence) growth in the future. (Hausmann et al. (2013), p. 35-37)

Hidalgo and Hausmann (2009, p. 10575) conclude from both findings - the strong association with income and the high capability of explaining future GDP per capita growth - that this is *"making a strong empirical case that the level of development is indeed associated to the complexity of a country`s economy."*

Since the authors have introduced the concept of Economic Complexity, one strain of literature has investigated factors which drive growth in Economic Complexity. These are (not exhaustive): *"different modes of taxation, intellectual property rights, institutions, demographics, transportation, digital connectivity and structural reforms." (Hidalgo (2021), p. 96)* Clearly, these factors are also drivers for GDP per capita. Thus, they are not helpful to further distinguish and understand Economic Complexity in the first hand. Furthermore, without having a theory at hand which attempts to explain the accumulation of Economic Complexity, these drivers cannot be contextualized. An underlying theoretic model of Economic Complexity will be introduced in the following chapter, but before doing so, we want to further distinguish the two indicators of economic development (GDP per capita and ECI) from each other by analyzing their effect upon different sources of changes in productivity.

First, in a basic economic model, assume that the price for a certain export good increases due to higher demand (an outward shift of the demand curve). Ceteris paribus, this will result in higher productivity for the producer of that export good and so overall GDP per capita increases within that country while the ECI remains unchanged. As such neither diversity nor ubiquity is affected.[6] Alternatively, we can look at efficiency gains due to economies of scale. Economies of scale affect productivity but not Economic Complexity as neither diversity nor ubiquity is

---

[6] In the following we assume that countries already have a RCA > 1.

affected. In conclusion, if (exogenous) changes in prices or changes in the production (due to e.g., economies of scale but not the technology) are the source of productivity increase, countries will increase their GDP per capita but not their productive capabilities - their ECI.

Note that these are immediate consequences of changes in prices or production efficiency. Things become more ambiguous if we consider non-immediate effects. For example, higher profits generated through higher (exogenous) demand might encourage firms to increase their investments and innovation activity which in turn could change their production structure.

The above examples show that growth in Economic Complexity is not about quantity and efficiency of production per se (however, overall, the goods must be assembled in a competitive manner to achieve RCA > 1) but about the economic structure of its country. Thus, within the framework where productive capabilities are the required inputs to produce a good, *a country can increase its Economic Complexity (ECI) by*

(1) Either accumulating new productive capabilities (and combine them with already obtained productive capabilities) to produce new products,
(2) And/or discovering products which can be produced with a combination of already obtained productive capabilities.

2.4 *Productive Knowledge* - A theoretical framework behind Economic Complexity

Along with the method of measuring Economic Complexity (Hidalgo and Hausmann (2009)), Hausmann et al. (2013) also propose a theoretic model which aims at explaining the diffusion and accumulation of productive capabilities. Importantly, the model revolves around the interconnection of knowledge within societies and is further developed in Hausmann et al. (2014) and Hidalgo (2015). However, their theory has not matured for widespread appliance yet (Gräbner et al. (2020, p. 31)).

With the idea in mind that the products a country exports must reflect the endowment of productive capabilities of a country – but that we cannot simply identify them - we now want to have a closer look at the types of potential productive capabilities. Following Hausmann et al. (2014, p. 15-18) let us imagine the required capabilities of an apple: “Next time you bite into an apple, consider that thousands of years of plant domestication has been combined with knowledge about logistics, refrigeration, pest control, food safety and the preservation of fresh produce to bring you that piece of fruit." (Hausmann et al. (2014, p. 15))

The apple example illustrates that even a rather simple product requires a vast amount of productive knowledge. Importantly, note how the authors contextualize the requirements of producing an apple in terms knowledge but not in terms of other requirements such as investments (e.g., infrastructure and machines for logistics and refrigeration), institutional quality (e.g., sufficient property rights "[…] to bring you that piece of fruit") or geographical conditions – which are all common drivers of economic growth in the literature.

So why should the ECI be a measure of the accumulated amount of productive **knowledge** – rather than that of productive investments or institutions - a country is holding?

One part of the answer lies in the way we compute the ECI: We classify hundreds of products by their ordering within the SITC4 or HS system. That is, naturally the productive requirements between 2 products differ more in terms of productive knowledge rather than in terms of other productive requirements. In other words, while the required productive knowledge certainly differs between the production of 2 different products, the remaining required productive capabilities (institutions or infrastructure) to produce the one good might be sufficient to produce also the other good. Using the Lego-Pieces analogy: Because we use a categorization by products (SITC4 or HS, that is, we include products sorted by SITC4 or HS in the adjacency matrix M_{cp} for computing the ECI) each product certainly requires some unique Lego pieces in terms of knowledge while the remaining required Lego pieces (productive capabilities) are more universally applicable.

The above theoretical confinement is important since we will later contrast *Economic Complexity* from *Institutional Quality*, as both are potential indicators of whether the NRC itself in resource abundant countries (i.e., whether natural resource abundance translates into long term economic growth is conditioned by the countries institutional quality or rather its level of Economic Complexity?).

Before the theoretic model behind the diffusion and accumulation of Economic Complexity (Hidalgo and Hausmann (2014)) is finally introduced, note that since its establishment, concept and index have been interpreted and used in various ways. (Maurya and Sahu (2022)) In this work, we follow the original definition of Economic Complexity where the *ECI reflects the accumulated amount of productive knowledge*.[7] (Hidalgo and Hausmann (2014), p. 9)

The theory behind Economic Complexity developed by Hausmann et al. (2014) *centers the capability to diffuse and accumulate productive knowledge* within a society as the fundamental driver behind economic development. To start with, consider that no individual alone can hold all the productive knowledge needed to produce all the different goods produced within one economy. Accordingly, individuals form organizations where all their different knowledge is combined to be able to produce complex products. Thus, the total amount of productive knowledge embedded in a society depends on the degree of specialization (~ the diversity) of each individual of the society rather than on how much knowledge each individual holds themselves.

This is familiar with Adam Smith's idea of the "division of labor" being the secret of the wealth of nations (but here the underlying reason of forming organizations is to efficiently divide the different tasks of the production process). In a modern interpretation of his theory, the division of labor's strength lies in its ability to give us access to a volume of knowledge that none of us could possess on our own.

Finally, *"The secret to modernity is that we collectively use large volumes of knowledge, while each one of us holds only a few bits of it. Society functions because its members form webs that allow them to specialize and share their knowledge with others."* (Hausmann et al. (2014), p. 15)

To explain income differences between countries, we need to explain why productive knowledge cannot easily diffuse through space. Hidalgo and Hausmann (2014) differentiate between two types of knowledge – "tacit" and "explicit" knowledge.[8] Explicit knowledge can be easily communicated (and thus saved in books or the internet too) from one person to another. Transmitting this type of knowledge is rather easy – e.g., the knowledge taught in

---

[7] E.g. Gräbner et al. (2020) use the ECI as an indicator of "technology"

[8] However, note that much of the theory on knowledge is not new. For example, Joel Mokyr (1990) explains the origin of the industrial revolution in terms of "knowledge bits which were then ready to be put together" and also distinguished between 2 types of knowledge in a similiar way.

schools is, to a large extent, explicit. Tacit knowledge on the other hand is hard to express and explain in words or pictures. It is mainly obtained by one's own experience. Hence, tacit knowledge is stored in brains and human networks. Productive knowledge - such as (competitively) producing apples or any other industry – is mainly tacit. It cannot sufficiently be learned by using books or other codified sources but by years of experience. Accordingly, the productive knowledge of any product is stored in the brains and human networks (firms) producing that product (hence, productive knowledge gets lost when firms close or workers retire) and the transmission of this knowledge works mainly through experience (i.e., working with or within this firm). "Because it is hard to transfer, tacit knowledge is what constraints the process of growth and development. Ultimately, differences in prosperity are related to the amount of tacit knowledge that societies hold and to their ability to combine and share this knowledge." (Hausmann et al. (2014), p. 16)

Before we further elaborate on how productive knowledge accumulates within societies, let us take the microeconomic perspective. Because learning from experience (obtaining tacit knowledge) is a long and costly (in terms of the investment taken into human capital) process, individuals specialize. Again, for a society to maximize its amount of productive knowledge in the first place it does not matter how much – but how different the stored productive knowledge is between each individual. Clearly, most products today are too complex for one individual to store all the productive knowledge needed. That is why individuals form organizations where they interact with each other to put all the different specialized knowledge together to produce complex products. (Hausmann et al. (2014), p. 17)

So far, we have established that when we compute the ECI we measure the amount of productive knowledge held by a society. Thus, the amount of productive knowledge must be reflected by the number - with respect to combinations - of different products that societies can produce. Accordingly, we measure the variety of firms and their variety of occupations and specializations needed to produce these products. However, as such the ECI also measures how capable a society is in forming tight networks where all the different productive knowledge (coming from firms, occupations and specializations) can be potentially combined in many ways to (1) decrease the yet missing productive knowledge to produce new products and (2) to cover more products which can be produced with the already existing productive knowledge. *"Economic complexity is a measure of how intricate this network of interactions is and hence of how much productive knowledge a society mobilizes. Economic complexity, therefore, is* *expressed in the composition of a country's productive output and reflects the structures that emerge to hold and combine knowledge."* (Hausmann et al. (2014), p. 18)

Eventually, we have introduced a theoretical framework which can help us to understand how productive knowledge is stored and how it diffuses through space. Yet, we haven't gone into more detail regarding how societies can acquire new productive knowledge or, in other words, how they can get more intricate networks. *But why do we care so much about this?*

Recall that institutional quality plays an important role in the natural resource curse literature. Again, we have distinguished two ways of how natural resource abundance affects economic development "via" institutional quality: First– in a mediating way – countries can be blessed (as we would expect in the first place) by their natural resource abundance if only their quality of institutions is sufficiently high enough. Second – natural resource abundance can harm institutional quality "directly" where the lowered quality of institutions then affects economic outcomes (so overall an indirect effect of natural resource abundance on economic development). Then, consider the recent pertinent empirical findings, where Economic Complexity overall takes a (similar-) mediating role within natural resource abundant countries. While the literature has offered possible mechanisms (channels) for how natural resource abundance directly or indirectly affects economic development via Institutional Quality – yet (to our knowledge) there hasn't been any attempt to explain the potential mechanisms of how natural resource abundance affects Economic Complexity (1) or how Economic Complexity can work in a mediating role (2).

In the following section, we are attempting to derive and constitute a mechanism for the causal relationship of (1). The introduced mechanisms are not new as they are taken from the existing literature on the Natural Resource Curse and enriched with theory on how Economic Complexity evolves. Even though this task is quite simple as the link between both (existing NRC meachanisms and theory on Economic Complexity evolution) is quite apparent, it hasn't been pronounced in the literature yet. Consequently, first the mechanisms explaining the NRC are introduced which we will then link to the concept behind the evolution of Economic Complexity – Connectedness and the Product Space.

2.5 Natural Resource Curse mechanisms

Above the theory of Hausmann et al. (2014) was introduced which describes the transfer of productive knowledge between individuals in general and as such builds a fundament of the knowledge-economy within a society. Thus, Economic Complexity is an endogenous approach to economic growth and development. Typically, endogenous growth theory is also concerned over positive externalities and spillover effects. (Hidalgo (2021))

We want to keep these – spillover effects - in mind as we look at some important mechanisms explaining the NRC since this will be the link to introduce the Economic Complexity theory.

The literature offers a lot of different explanations - and so channels – as to why natural resource abundance might be detrimental for economic development. In general, this makes it difficult to determine specific causal channels and their importance (James, 2015).

The potential channels through which abundance in natural resources negatively affects economic development can be subdivided into direct and indirect channels (A. Lashitew & Werker, 2020). Direct channels mainly comprise market-based explanations such as the Dutch disease or (high) the price volatility of commodities. Indirect channels affect economic development via a deterioration of institutions or human capital (education).

How do we define natural resource abundance? There are several ways to account for a country's endowment in natural resources. Overall, we can distinguish between the abundance in stock (not yet extracted) and dependence in output (e.g. the share of natural resources in exports or GDP - per capita). All these measures underlie endogeneity issues and are sensitive for the empirical finding of a NRC. (Ramez et al. (2016), pp. 13) The issue of measuring natural resource abundance will be revisited in more detail in chapter 3.

2.5.1 Institutional resource curse explanations

Natural resources may also affect economic development indirectly through the deterioration of institutional quality or fewer investments into human capital.

Gylfason (2001) argues that resource abundance gives a "false sense of security" and shows evidence that resource abundant countries come along with reduced years of schooling and public expenditures in education. Indirect political/institutional channels are multifaceted and take an important role as to whether or not countries can avoid the curse.

For testing the role of institutions, Mehlum et al. (2006) show that the resource curse vanishes if one controls for the ex-ante (initial) quality of institutions. The authors have replicated the pioneering work of Sachs and Warner (1995) who prefer on the Dutch disease explanation. Mehlum et al. (2006) conclude that the Dutch disease explanation becomes less seminal and refer to a *rent-seeking* model where grabber friendly institutions attract more scarce resources (skilled labor and capital) to unproductive activities.

In countries with low quality of institutions, i.e. authoritarian and weak rule of law (..), big stocks or explorations in natural resources can have detrimental effects on the growth experience. Rent-seeking behavior of the *elite* hinders rents being used in a way that benefits long term economic development. It can be summarized that especially oil "tends to make authoritarian regimes more durable, to increase certain types of corruption, and to help trigger violent conflict in low- and middle-income countries." (Ross (2015) p. 239)

The role of institutional quality within the resource curse is decisive and much literature exist which further analyze the links between particular channels which fall under the umbrella term of "Institutional Quality". However, the empirical finding of a Natural Resource Curse is no empirical regularity. (Badeeb et al. (2017); Brunnschweiler & Bulte (2008); Ross (2015))

2.5.2 Market-based resource curse explanations

The *Dutch-disease* is an early and popular explanation and was formally explored by Corden and Neary (1982) after the discovery of natural-gas sources in the Netherlands. The authors distinguish between two effects which result from a boom (induced through exploration or rising world market prices) within the tradable commodity sector. Importantly, both effects harm the other exporting sectors of the economy – the so called "crowding out". First, the "spending effect" decreases competitiveness of the exporting manufacturing (or agricultural) sector because the "additional" income from the booming commodities causes inflation and overvaluation of the real exchange rate and thus, the prices of the other traded goods become more expensive on the world market. The "resource-movement effect" originates in the higher profitability of the booming sector which draws mobile factors of labor and capital from other sectors through higher wages and rents. However, Corden and Neary (1982) note, that to come into effect, the “resource-movement effect” requires that the booming sector is sufficiently labor intensive while having full employment. Ross (1999) notes that with these assumptions the resource movement effect becomes rather neglectable since most commodity abundant economies are rather poor and have unemployment.

Theoretically, any type of tradable boom involves these macroeconomic and structural changes of the Dutch disease model. In principle, it does not require natural resources to evoke these macroeconomic and structural changes (van Wijnbergen, 1984). However, the demand (and so its revenues) and the rents for oil, gas and minerals are typically high which eventually drives the potential structural changes.[9] Hence, the Dutch disease model is prone to natural resource booms.

But why are natural resources in particular supposed to slow economic growth? *Structural change – the movement of labor and capital to different sectors – is not harmful itself.*

The first argument evolves around the characteristic “boom and bust” cycles (initiated through rapid changing natural resource prices) and the following structural changes which tend to be short lived. (van Wijnbergen, 1984)

At this point it makes sense to introduce the second market-based resource curse model before we come back to the second argument.

These commodity “boom and busts” also affects subsequent markets and institutions through high volatility of revenues. In general, high volatility raises uncertainty in decision making. Hence, the high volatile nature of many natural resource world prices increases uncertainty in related markets and thus makes effective planning and investment difficult. Another harm to growth arises through public financing and spending as Davis & Tilton, (2005) argue that volatile commodity revenues promote pro-cyclical public revenues.

[9] In contrast to agricultural commodities, extractive commodity production is limited to its scarce sources and hence rents are higher Collier and Goderis (2008).

Coming back, the second (Dutch) “disease” argument is still concerned with structural changes. Again, why should resource-led growth be a harm? The *crowding out* of other industries – through inflation and structural changes - in favor of natural resources is assumed to be harmful because it is said that especially the manufacturing sector generates spillovers which are key for economic development. Accordingly, the manufacturing sector is also referred to as the “engine” of growth, while on the other side mining and extractive industries are seen as “enclave” industries with few “forward” and “backward” linkages. (Deacon and Rode (2015)) [10]

Intuitively, this seems to be the case as most developed countries have established manufacturing sectors. *But how do we evaluate which products or sectors are more prone for long-term growth than others?*

For instance, Gouvea and Vora (2015) run a single-index model and confirm the superiority of manufacturing exports over mineral & fuels and agriculture. However, their model is built upon the historic data and the stability of the different types of exports. Gouvea and Vora (2015) take this into account and hypothesize that future terms of trade of natural resources might increase because previous rents of industrialized countries will decrease due to *“commoditisation”* of manufacturing.

At the same time, we do not know how to measure “spillover-potential”.

Finally, note that all resource curse explanations have in common that in one way or the other they „crowd out“ the development process of the other non-resource sectors. As James (2015, p. 4) puts it, this is a necessary condition of the resource curse to exist, otherwise „an economy would not be worse off after a resource is discovered and extracted.“

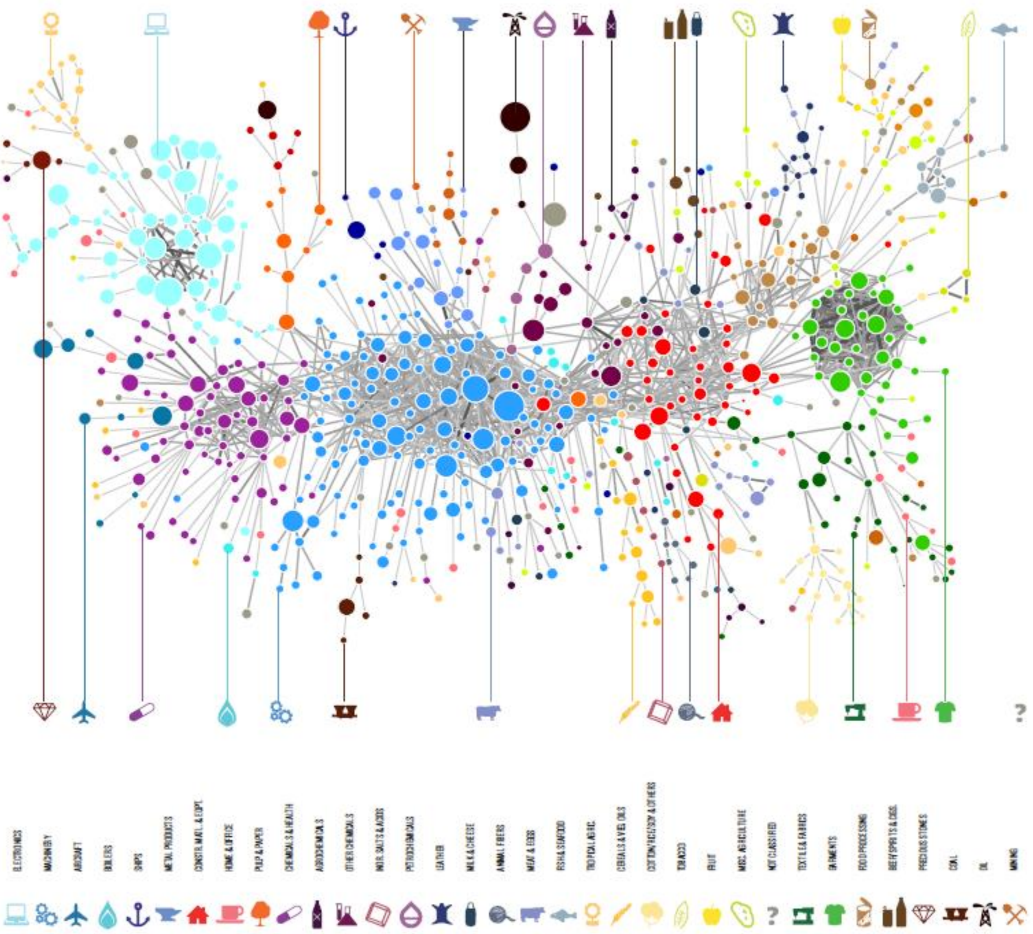
---

[10] However, so far there was no clear consensus if mining industries are enclaves with few forward and backward linkages, see (Davis & Tilton, 2005). Clearly, the product space now gives quantitative insights.

2.6 How does Economic Complexity evolve?

Spillover-potential describes the potential of an economic activity (here: producing a specific product) to initiate another economic activity due to e.g. their connection in the supply-chain. Extractive industries have been termed “enclave industries” (so this is the main argument of the Dutch Disease NRC-explanation) because the spillover potential of products such as petroleum, natural gas, metals and co. is assumed to be small as these products form the beginning of often short supply-chains. When we eventually ask ourselves how countries can expand their Economic Complexity, we can use the same idea about spillover potential and enclave theories to explain why metals, fuels and co. are so called enclave industries.

Figure 3: The Product Space

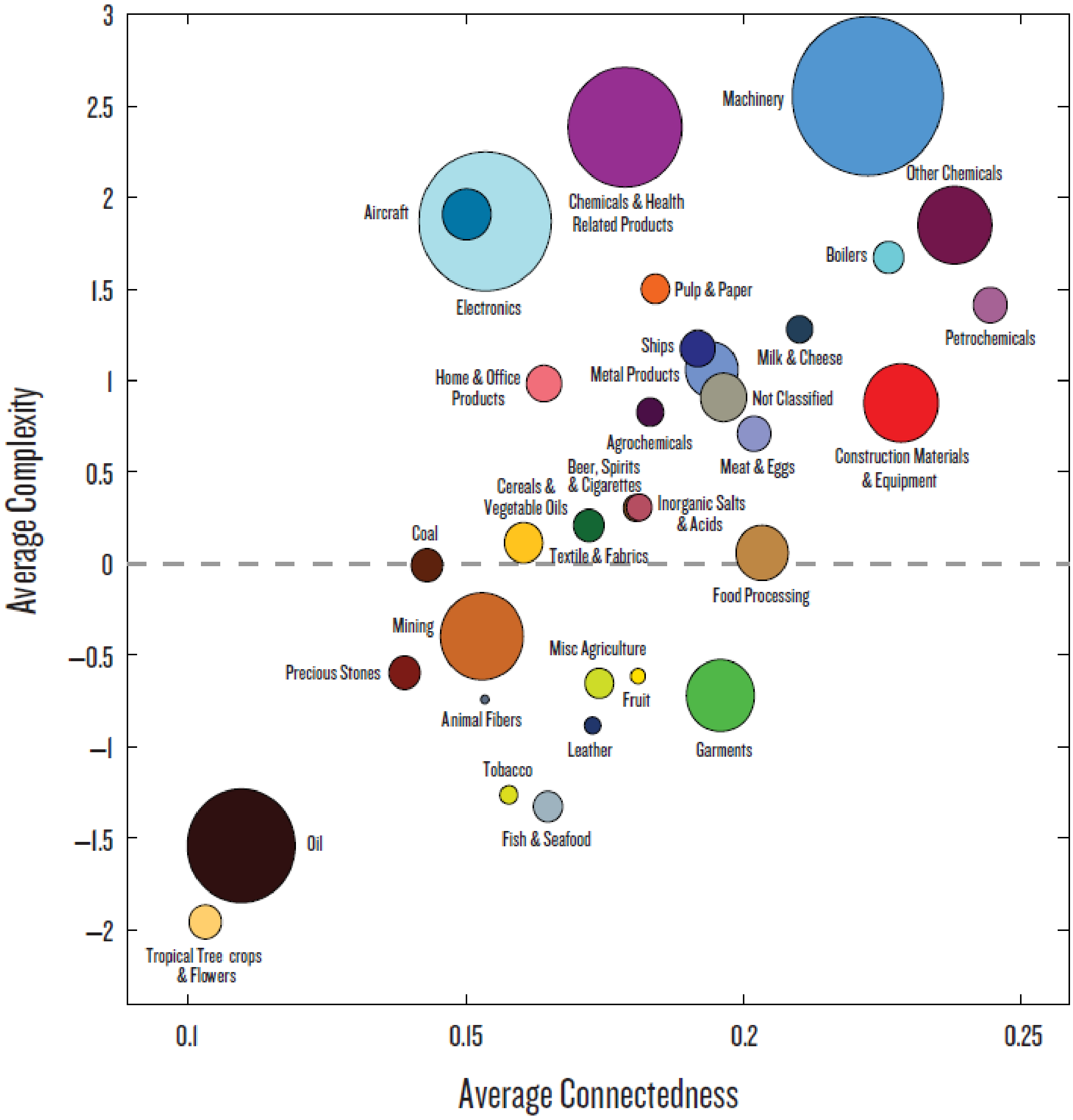


Source: Extracted from Hausmann et al. (2014), p. 52.

For now, consider figure 3 which displays the so called ”Product Space”. It shows all different kind of products (according to the HS or SITC4 system). All these products in the space above are structured by their connectedness between each other, i.e. two products are highly connected when they are depicted proximate to each other. This is the case when the probability is high that both products are usually co-produced by countries. Then, under the general assumption that the products a country produces are reflecting the different amount of productive capabilities (Lego pieces of knowledge – or, in a not technical-only term: technology) a country possesses, the Product Space shows us how much 2 products have in common in terms of the required productive knowledge. The size of the different nods (product groups) reflects the average complexity ((PCI), recall, the computation of the PCI is analoug to that of countries – the ECI) of this product group.(Hidalgo et al. (2007))

Consequently, in terms of the Dutch Disease argument: Spillover potential is high when the required productive knowledge for some already produced good is similiar to a not yet produced good (proximate nods in the product space). If proximate enough, not much new productive knowledge needs to be obtained. Acquiring new productive knowledge (for example becoming active in a new industry) is assumed to be difficult. Remember, according to the theory of Hausmann et al. (2014) productive knowledge is mostly transferred between individuals through experience (tacit knowledge) and since there is no experience in a yet not explored industry, the difficulty to acquire new productive knowledge is also referred to the ”chicken and egg” problem (...what existed first, the egg or the chicken?).

Figure 4: Average Complexity by average Connectedness



Source: Extracted from Hausmann et al. (2014), p. 54.

Figure 4 gives us quantitative evidence of mining, coal and oil really being ”enclave” industries. On the x-axis we see the average connectedness of a community. The y-axis gives us information about the average complexity of this community (the PCI). It is no surprise, that the more complex communities (products) have a higher connectedness a they require pieces of productive knowledge from all kind of product communities. Also note, the size of the circles (product groups or clustered ”communities”) stands for the share in the worlds exports (value).

After all, we can see that mining, coal and oil all have relative low PCI (i.e. the countries which also extract and sell such natural resources have in average a low diversified product portfolio).[11] More importantly, consider the average connectedness of these natural resources to see, that the productive knowledge needed to extract these natural resources is not really needed in other product communities. Finally, figure 2 can also be read as a map which shows paths to products and where closer paths were easier to reach (i.e. to obtain the needed productive knowledge) in the path and are probably still today.

Recall, that the ECI contains the information of the PCI (and vice versa) and thus, a products general connectedness (”spillover potential”) is included when computing the ECI.

2.7 The case of Latin America

The motivation to investigate the relationship between Economic Complexity, Economic Growth and NRA in Latin America mainly stems from the lack of empirical evidence for this region. As we have now covered most theoretical knowledge, we want to highlight some special characteristics of Latin American countries which shall be considered for the remaining study.

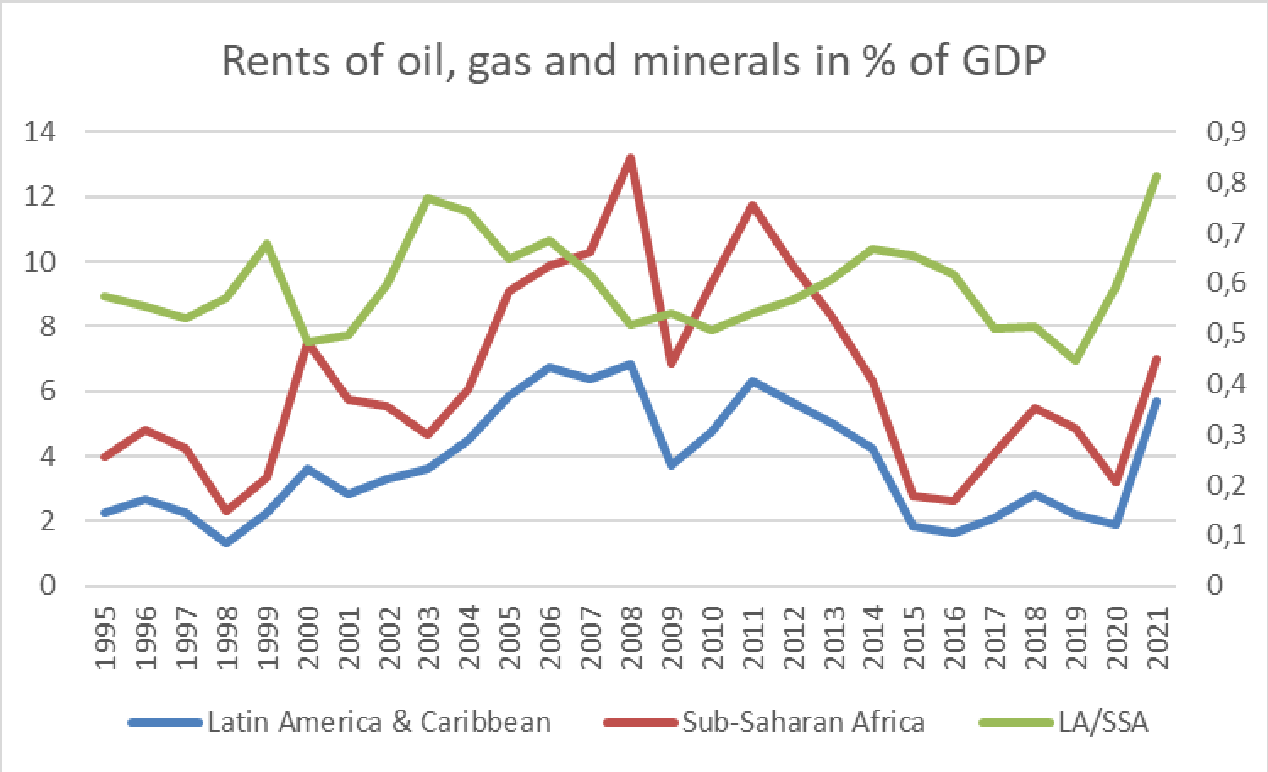
The literatures stand on whether NRA in Latin America has been detrimental for economic growth in the past is ambiguous. For empirical tests on the whole region, Haber and Menaldo (2012) investigate whether NRA affects democracy and from the empirical evidence they conclude that there is at most no connection between NRA and democracy in Latin America. Papyrakis and Pellegrini (2019) distinguish between NRA and Natural Resource Dependence (NRD, later more on these measurements) and investigate their association with economic growth. The authors are concluding that: ”Latin American countries show a mixed picture, confirming the idea that the resource curse is not a deterministic phenomenon and that dependence on, rather than abundance of, natural resources is associated with developmental failures.” (Papyrakis and Pelligrini (2019), pp. 13)

---

[11] Recall the 2nd dimension for complexity is ubiquity. Please consult Hausmann et al. (2014) in order to understand how the authors control for ubiquity in naturally limited products such as diamonds (as their are naturally quite non-ubiquitous).

As much of the NRC literature points towards Sub-Saharan African countries being the potentially most naturally-resource-cursed region, we want to provide comparative descriptive data of the two world regions.

Figure 5: Rents of oil, gas and minerals in % of GDP by region.



Source: Own calculation; data extracted from World Bank.

Figure 5 shows the course of potentially harmful natural resource rents (sum of oil, gas and minerals in % of GDP (left axis)) for both Latin America and Sub-Saharan Africa. The green line reflects the ratio of both (Latin American rents share over Sub-Saharan African rents share). In average, between 1995 and 2021 Sub-Saharan African countries have 67% higher rent shares in GDP than Latin American countries and thus, relatively more economic activity is assigned to the extraction of oil, natural gas and minerals.

Clearly, the volatility of the rents in figure 5 are largely caused by quickly changing commodity prices (refer to appendix 2, to see that the rents roughly follow the oil price) and thus, the actual economic activity (in terms of input/output) does in general not follow the course of the rents.

Importantly, note how the rents ratio between Latin America and Sub-Saharan Africa (green line) tends to be low (i.e. SSA is extracting and selling relatively high amounts of oil, gas and minerals) in times of high rent-shares in GDP and thus in times of high commodity prices (assuming that all other economic activities remain the same). This finding indicates that the production of oil, gas and minerals reacts more strongly to the respective price changes in Sub-Saharan Africa than in Latin America…

For the following empirical investigation, we take away Latin American countries extract fewer oil, gas and minerals (in terms of rents of GDP) than Sub-Saharan Africa.

Eventually, we want to highlight some important characteristics of Latin America which are important for the empirical investigation later on. First, it is commonly known that Latin America is one of the most unequal (in terms of income and land) regions of the world today. Engerman and Sokoloff (2002) propose that this inequality is a relict of colonial times when the institutions were formed from the Spanish and Portuguese colonizers. Accordingly, because the region was relatively abundant in labor and fertile land (soil and metals), the colonizers created institutions which were suitable to maximize the profit from these abundancies. The economic activities were often operated and efficient on large scales. Eventually, according to Engerman and Sokoloff (2002) is the relatively high inequality in Latin America to be attributed to persistent institutions.

Secondly, consider inequality from an Economic Complexity perspective and remember the underlying theory about the difficulty of transferring productive knowledge. Clearly, the inherited unequal institutions and the factor endowments do not only affect unequal payment but in the first step they also affect the way individuals (can) learn, specialize and form their organizations. Accordingly, productive capability/Economic Complexity co-evolve with inclusiveness of institutions. (Hartmann et al. (2017), pp. 77)

Note that we have then also identified a potential driver – factor endowments/natural resource abundance – which may cause institutions and Economic Complexity to deteriorate. We will focus on this direction of causality in the following chapter.

2.8 Effect of NRA on Economic Complexity: Reviewing Avom et al. (2022)

Avom et al. (2022) test the effect of NRA (rents of oil, gas and minerals per capita) on ECI, based on the system GMM approach. If not controlled for, this model is endogenous by construction as both dependent and independent variables variate with the commodity prices of oil, gas and minerals.

In more detail - a country receives a higher ECI in a certain year if many of its exported goods achieve a Revealed Comparative Advantage (RCA). In order to affect the ECI at all (a discrete threshold) exports need to fulfill the following condition: RCA for a country (c) for a product (p) is found if RCA > 1 (refer to chapter 2.2 again if necessary). This is the case when the share of the exported good p (in $) in country c in the global exports ($) of that same good is larger than the countries expected share of exports in that good (where the expected share for country c in p is equal to: countries c total exports ($) over global exports ($)). (Hausman et al. (2013), p. 24-25)

So far so good. The endogeneity issue now arises when we take into account that when resource rents increase, also the expected share of exports - the denominator of (1) (which remains constant for any other product) - increases. Thus, during times of high commodity prices, products which were previously close but above an RCA of 1 will ”lose” their RCA and as a consequence the ECI will decrease – but by construction and not because manufacturing activities shrinked.

In fact, Hausman et al. (2013, p. 25) take volatile commodity prices and their effect on the RCA into account: "Going forward, we moderate changes in export values induced by fluctuations in commodity prices by using a modified definition of RCA in which the denominator is averaged over the previous three years."

One way to circumvent the endogeneity issue is to include a control variable for the commodity price changes only (averaged over the last 3 previous years, as Hausmann et al. (2013) do in their RCA). Having the ECI as dependent variable and commodity prices (avg. 3 previous years) control for the changes in ECI induced by the changes in RCA due to changes in commodity prices, resource rents (per capita) should only affect the ECI via their intrinsic channels (i.e. crowding out).

2.9 Quiescene

From this chapter on we give concise insights into the pertinent empirical literature to build a valid empirical model and to interpret our empirical results later on.

In Hausmann and Hidalgo (2011), the authors push forward the implications of their developed theory about the accumulation of productive knowledge. “Countries with few capabilities will have a lower probability of finding uses for any additional capability than countries with many capabilities as the number of potential combinations increases as a power of the number of capabilities available in a country. Hence, countries with few (many) capabilities will face low (high) incentives to the accumulation of additional capabilities.” (Hausmann and Hidalgo (2011), p. 313)

The authors therefore build a model upon these implications and fit it to empirical data. The model confirms the diverging dynamics between countries over time, where productive capabilities travel slowly and countries with many productive capabilities evolve even faster than those with few productive capabilities. Thus, Hausmann and Hidalgo (2011) call this implication the *quiescene trap.*

2.10 Economic Complexity and Diversification

Is the ECI just another measure of export diversification? Since one component of the ECI considers the diversity of a country’s exports we might think so. However, recall the method of reflection shown in chapter 2.2: In a nutshell: We also take into account the complexity (the difficulty) of a product (how many other countries can produce this product), which accounts for specialization. In fact, it is a common misconception in the literature to understand the ECI as an improved measure of diversification. Hidalgo (2021) shows that the association between ECI and diversification is *orthogonal*.

That richer countries tend to have more diversified export structures has been already observed by researchers such as Michaely (1958).[12] When economies grow (on a per capita basis) they usually start engaging in new economic activities rather than just increasing the number of their already established exports. More recently, Klinger and Lederman (2006) have empirically shown that export diversification increases with GDP per capita only until a certain level (lower middle-income) at which then additional innovation activity declines as the income level further increases. The authors argue that is due to the changing nature of innovation: Initially, poor countries merely increase their export diversity by adapting to already existent products and technologies. Once the country has reached the technological frontier, diversification slows down as innovation now requires the creation of truly “new” products. (Klinger and Lederman (2006), p. 4-5)

If, in general, economic development materializes itself with a more diversified export structure, we should ask ourselves “What are drivers of export diversification?” “What makes societies engage in *new* economic activities?”

In Ricardo´s basic model under free trade, trading patterns between 2 countries are formed over differences in productivity. Thus, in this basic model causation runs in one direction: Changes in productivity causes changes in what goods are traded/exported. However, trade liberalization can be dangerous as undesirable specialization patterns such as specialization on natural resources (recall the implications of the Product Space) can lead to path-dependence, that is, it is hard to move away from specialized economic activities.

In this respect, Gräbner et al. (2020, pp. 6) note that: “In this respect, evolutionary accounts are in agreement with the literature on economic complexity which stresses that *what you export matters*.”

---

[12] Michaely (1958) was one of the first who empirically explored this finding. More recently, Klinger and Lederman (2006) show that export diversification increases with GDP per capita level up to a certain level (lower middle-income), at which then export diversification slows down. They find that additional innovation activity declines as the income level further increases. The authors argue that is due to the changing nature of innovation: Initially, poor countries merely increase their export diversity by adapting to already existent products/technology. Once the country has reached the technological frontier, diversification slows down as innovation now requires the creation of truly “new” products. (Klinger and Lederman (2006), p. 4-5)

2.11 The link between NRA and Institutional Quality

The direct link between Institutional Quality and Natural Resource Abundance, however, is not unambigious. Even though there is much literature emanating empirical evidence and mechanism suggesting that NRA negatively affects Institutions, there is also seriously contradicting evidence. For example, evidence of *NRA fueling authoritarism* (Ross (2015)) is contradicted by Haber and Menaldo (2011). They thorougly conduct time series techniques in order to find a causal relationship between NRA and Institutions but cannot find it, rather they find a positive effect of NRA on democracy.

Torvik (2009) and Mehlum et al. (2006) show empirical evidence that countries with a certain level of institutional quality prevent the negative effects of NRA on growth but achieve average growth rates (in relation to the sample).

2.12 Strategies to empirically test the NRC

Recall, that all different potential channels directing from NRA to economic growth have in common that in one way or the other they crowd out the development process of the other non-resource sectors. As James (2015, p. 4) frames it, this is a necessary condition of the NRC to exist, otherwise „an economy would not be worse off after a resource is discovered and extracted. "

Empirical testing faces two immanent issues. First, testing the short-term effects on growth after a discovery or commodity price hikes is misleading because GDP moves in the same direction during booms and busts (and booms potentially cause crowding out non-resource economic activities). Because of this issue, researchers are turning their attention towards long-term growth or other economic development indicators.

Another issue arises with the measurement of NRA. *How to measure the abundance of natural resources of a nation?* Early studies used the ratio of natural resource exports over GDP but this measure is likely to be endogenous by bad policy as bad policy decreases GDP and hence countries with bad policy will end up having high ratios of natural resource exports over GDP. Brunnschweiler and Bulte (2008) hence distinguish between *natural resource dependence* (natural resource exports over total exports or GDP) and *natural resource abundance (NRA).*

Until now, when we have referred to NRA, we did not refer to a specific measure but to a nation having plenty of natural resources. Lastly, there is a third measure used in the literature - *natural resource wealth* – which measures the (estimated) stock of certain natural resources under the ground of a nation. But also, this measure has been criticized to be endogenous to GDP as well as the estimated stock and explorations depend on the price of the commodity.

Consequently, some studies try to circumvent endogeneity by measuring resource wealth (the least endogenous measure) or applying 2SLS or “endogenous” estimators such as GMM.

A time-series approach has been conducted by Collier and Goderis (2008). They use a VECM and find a positive short-term effect of natural resource prices on GDP and a negative long-term effect on GDP and consequently confirm the natural resource curse.

Furthermore, note that the outcome (“curse or blessing”) for which we are testing the effect of NRA and ECI on long-term economic growth also depends on time. James (2015) confirms the NRC hypothesis (in a global sample) for the period of the late 60’s to the early 90’s but declines it for the years afterwards. This finding is also due to the oil crisis (1973) which has led many (Latin American) oil-exporting countries to a debt crisis afterwards.

3 Data

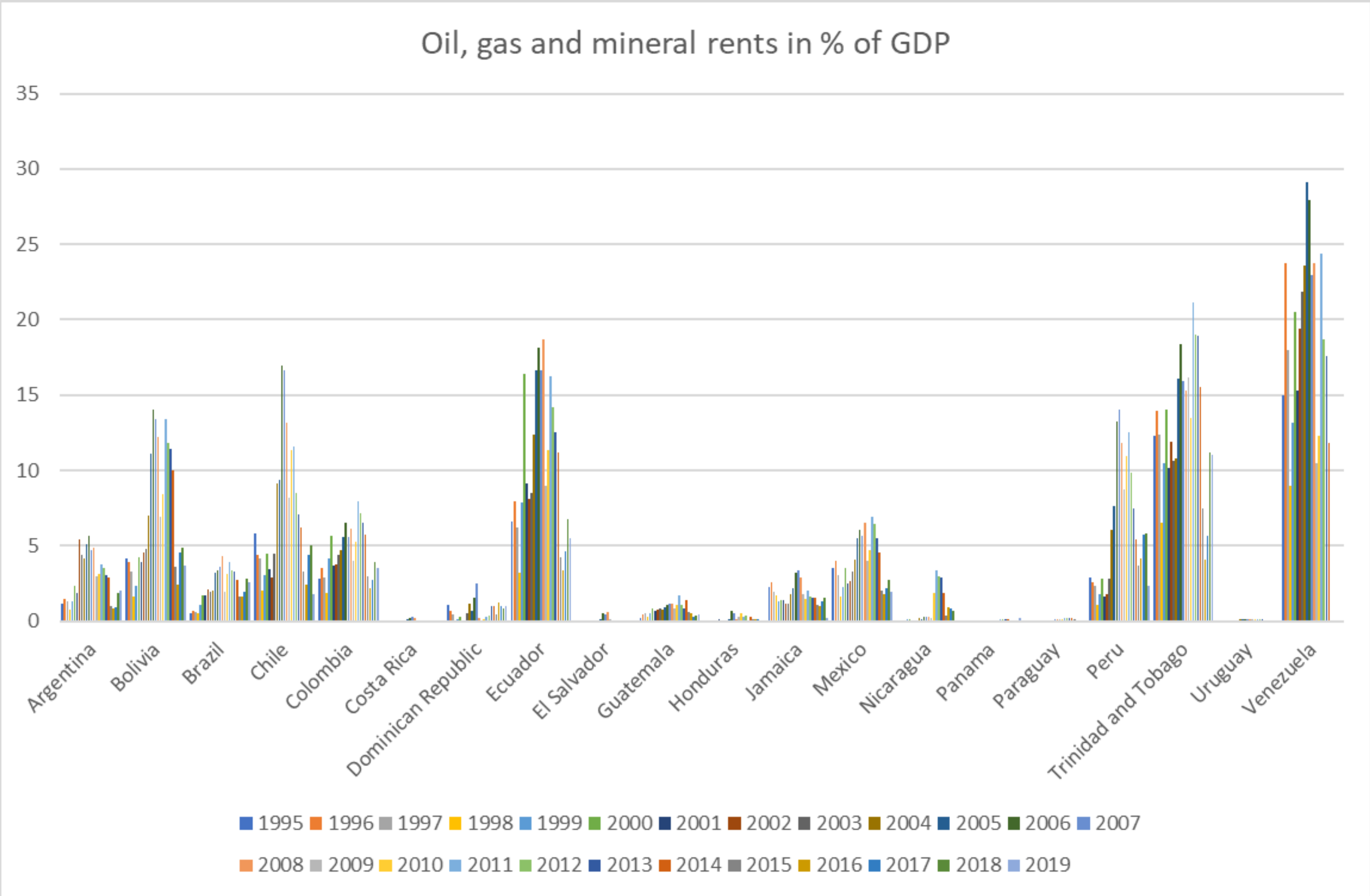
The constructed dataset is a panel series for 20 (N=20) Latin American countries (the 20 largest in terms of population size) from 1995 to 2019. Please find below the different variables we have obtained. After all, our panel series is not fully balanced: We miss data in general for institutions and for some specific countries-years we miss values for several of our variables.

Table 3: Data

Variable	**Meaning**	**Definition**	**Source**
growth9519	Average GDP per capita growth between 1995-2019.	(“rgdpna” of 2019 over “rgdpna” of 1995)*100 / 25	Computation follows Sachs and Warner (1997); “rgdpna” is taken from PWT10.01 (Fenstra et al. (2015). As we are not comparing levels or living standards across countries at a certain point in time but growth rates (over time) we use *real* GDP (”rgdpna”) data – extracted from national accounts - which is based on constant national prices (in PPP 2017US$). (Feenstra et al. (2015), p. 3150-3156)
ECI	Economic Complexity Index; measure of the relative knowledge intensity of an economy (here, computed	See chapter 2.2.	The Growth Lab at Harvard University, 2019, "Growth Projections and Complexity Rankings", Harvard Dataverse, V3 https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/XTAQMC

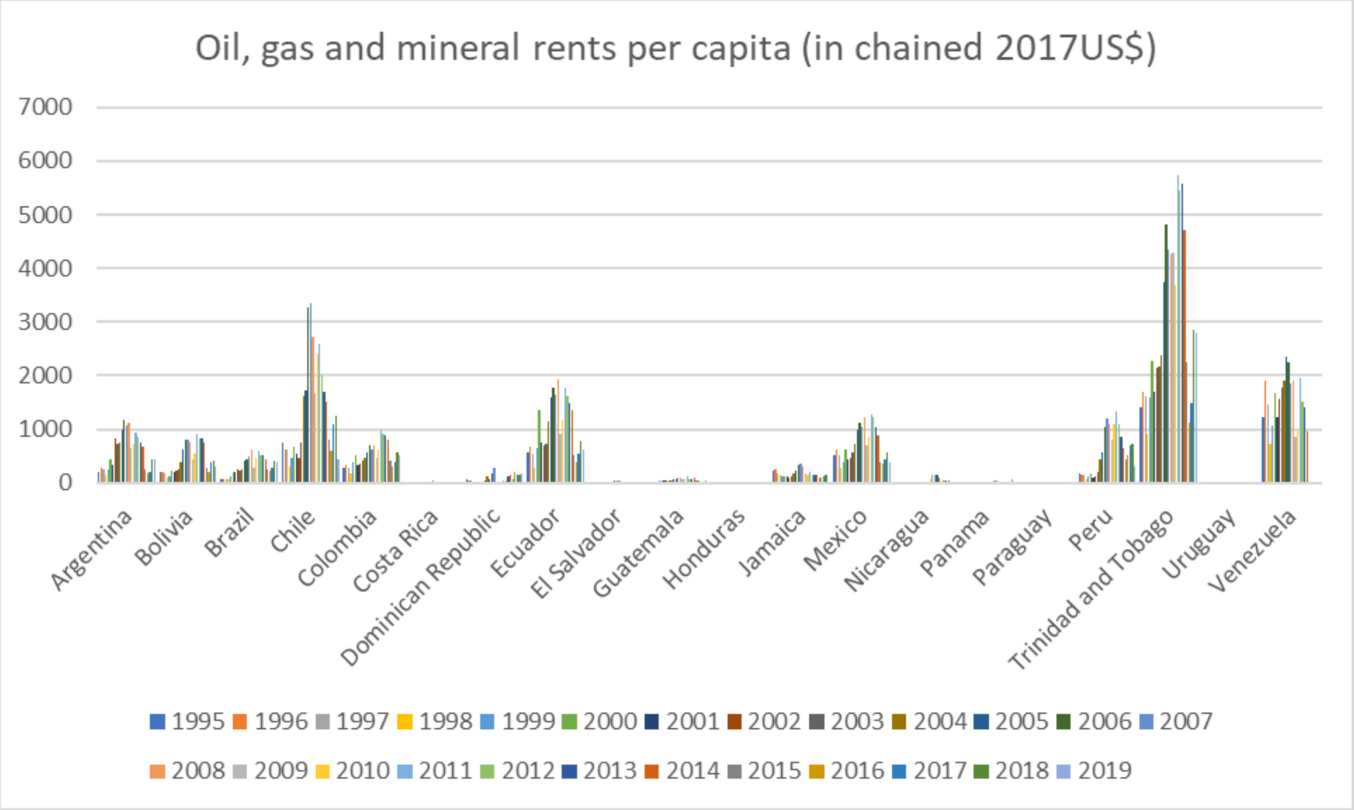
	via HS trade data)		
NRA	Natural resource abundance	Logarithm of the average (1995-1999) per capita rents (sum of petroleum, natural gas and minerals).	Data on yearly per capita rents (in % of GDP) for each type of natural resource different is taken from the World Bank - World Development Indicators (WDI) and is then multiplicated by the World Banks GDP per capita data in order to get per capita rents in absolute values.
initgdppc	GDP per capita in 1995	Ln("cgdpo" of 1995 / population in 1995)	"cgdpo" data is taken from PWT10.01 and is the most suitable GDP data for comparing productivity across countries at a single point of time.
NRD	Natural Resource Dependence	Rents (oil, gas or minerals) are the difference between the value of production at world prices and their total costs of production. Minerals included in the calculation are tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate.	World Bank (WDI)
corruption	Control of corruption	The natural logarithm of the 1996 countries ranking within a global sample (0-100 - 0 for low control of corruption).	Worldwide Governance Indicators www.govindicators.org Downloaded from the QOC dataset from the University of Gothenburg.
hc	Human capital	Years of schooling	Extracted from the PWT10.01 dataset. (Fenstra et al. (2015)

Figure 5: Natural Resource Dependence: Oil, gas and mineral rents in % of GDP



Source: Own calculation.

Figure 6: Natural Resource Abundance (NRA): Oil, gas and mineral rents per capita (in chained 2017US$)



Source: Own calculation.

4 Method (empirical approach)

To estimate the effect of NRA on economic growth, conditioned by Economic Complexity we use cross-sectional regression methodology (OLS estimator). The design of our resource-growth model goes back to Romer (1986) as we follow an endogenous approach to long-term economic growth. The way in which we introduce natural resource richness goes back to the work of Sachs and Warner (1995). To investigate the effect of NRA on long-term economic growth and the effect of NRA - conditioned by Economic Complexity – on long-term economic growth, we estimate the following equation:

$$growth9519 = \alpha + \beta * (NRA * ECI) + \delta(C) + \varepsilon \qquad (1)$$

Where growth9519 measures the average GDP per capita growth between 1995-2019. NRA*ECI is an interaction term capturing the conditional effect of NRA on growth9519.

We introduce several control variables for robustness checks. First, to investigate the association between growth9519 and natural resource richness we use two further indicators: NRD and OilNRA, where the motivation to consider oil rents per capita (OilNRA) solely is coming from the literature pointing towards oil being the potential most detrimental natural resource for sustained economic growth. We further control for potential convergence dynamics by letting initial (1995) GDP per capita enter the growth regression. We also control for human capital (based on years of schooling). Lastly, we let our different indicators for natural resource richness interact with ECI and an indicator for institutional quality (control of corruption) to investigate whether the conditional effect of NRA on growth9519 differs between both measures.

A further note on our empirical methodology: Clearly, having only 20 observations (N=20) restricts the empirical value of our estimation results. Due to data availability, I do not use panel or time series approaches. We follow the empirical model previously used in the pertinent literature (e.g. Sachs and Warner (1995/1997), Mehlum et al. (2006) or Gräbner et al. (2020). To our knowledge this is the first investigation of the conditional effect of NRA (conditioned by ECI) on long-term growth in Latin America. We therefore are interested in the general directions and significance of our variables of interest, but not the magnitude (and measures to take care to isolate the pure channel effect).

5 Empirical results and discussion

In the following I report the different empirical results. The goal of this procedure is to approach a standpoint on which we can conclusively interpret the results.

First, we simply test the effect of NRA, NRD and OilNRA (natural logarithm of oil rents per capita) on "growth9519":

Table 4: Effect of NRA, NRD and OilNRA on growth9519

explanatory variable	**coefficient value**	**t-statistic**
NRA	-0.109	-0.63
NRD	-17.685	-1.67
OilNRA	-0.166	-0.97

Note: The sample size of N=20 requires higher t-statistic values. Our preferred measure for natural resources is NRA.

All three different indicators for natural resource richness in 1995 are having a negative effect on the average long-term GDP per capita growth (1995-2019), though insignificant. We cannot compare the marginal effects between the three measurements but their significance: The effect of NRD on growth tends to be the most significant indicating that high natural resource dependence indeed came with rather slow economic growth between 1995 and 2019. Recall, that the measure of NRD is likely to be endogenous to poor policy making or grabber-friendly institutions. NRA on the other hand is presumably less endogenous and is also found to be rather negatively associated with growth.

Next, we report the association between growth9519 and initial institutional quality (indicated by control for corruption) and initial level of Economic Complexity.

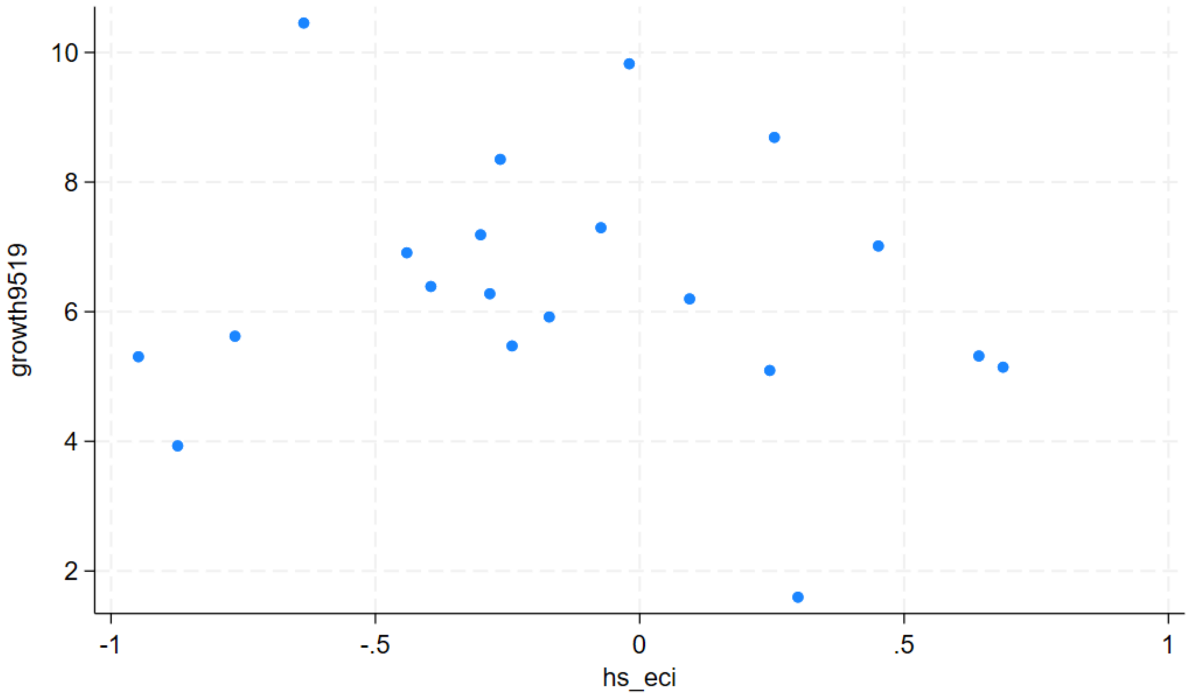
Table 5: Effect of initial institutional quality and ECI on growth9519

explanatory variable	**coefficient value**	**t-statistic**
ln_corruption	1.0587	1.41
ECI	-0.474	-0.48

Note: The sample size of N=20 requires higher t-statistic values. Our preferred measure for natural resources is NRA.

Countries with higher initial Economic Complexity in 1995 tend to have grown slower over the following 25 years. The literature generally suggests that high growth rates can be explained through technological catching-up. Also introducing control variables doesn't change the sign of general direction of this relationship.

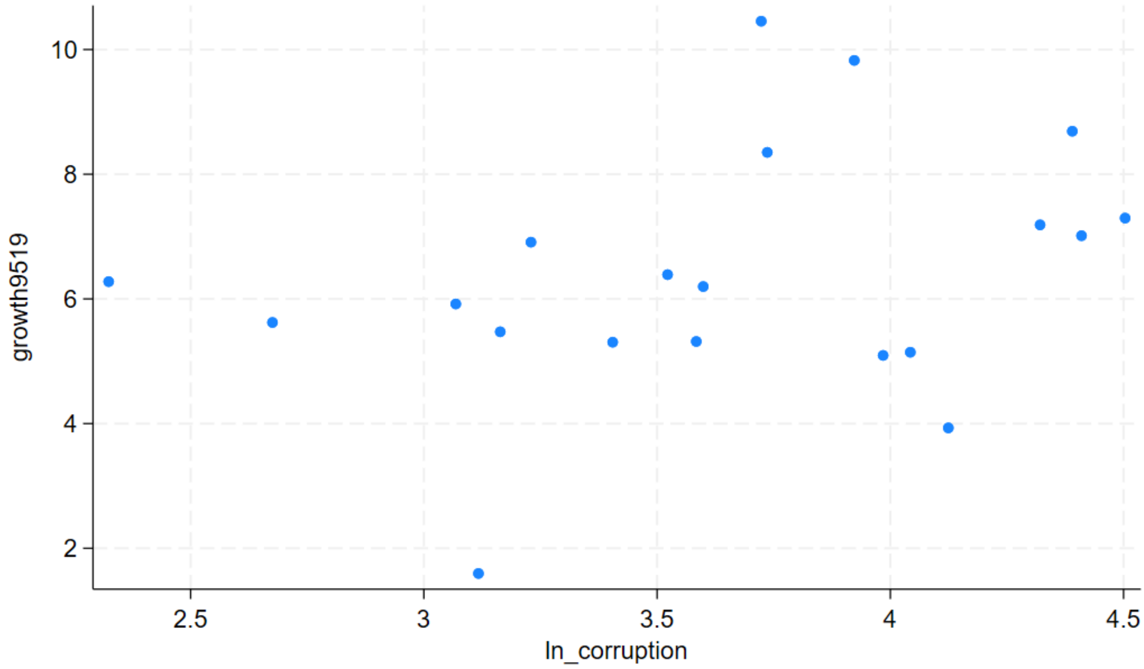
Figure 7: Association between ECI and growth9519



Note: Own calculation.

Below in figure 8 we see the association between initial corruption control and average growth which is as expected positive.

Figure 8: Association between corruption control and growth9519



Note: Own calculation.

The usage of initial levels of institutional quality or Economic Complexity when investigating its effect on long-term growth is common in the literature but is certainly arguable, even though these variables tend to change slowly over time.

Finally, we interact measures of natural resource richness with ECI and the indicator for corruption control.

Table 6: Conditional effect of NRA, OilNRA or NRD on growth9519

explanatory variable	**coefficient value**	**t-statistic**
ECI*NRA	-0.067	-0.33
ECI*OilNRA	-0.106	-0.44
ECI*NRD	-15.33	-0.66

CORRUPTION*NRA	-0.0147	-0.33
CORRUPTION*OilNRA	-0.029	-0.65
CORRUPTION*NRD	-3.576	-1.17

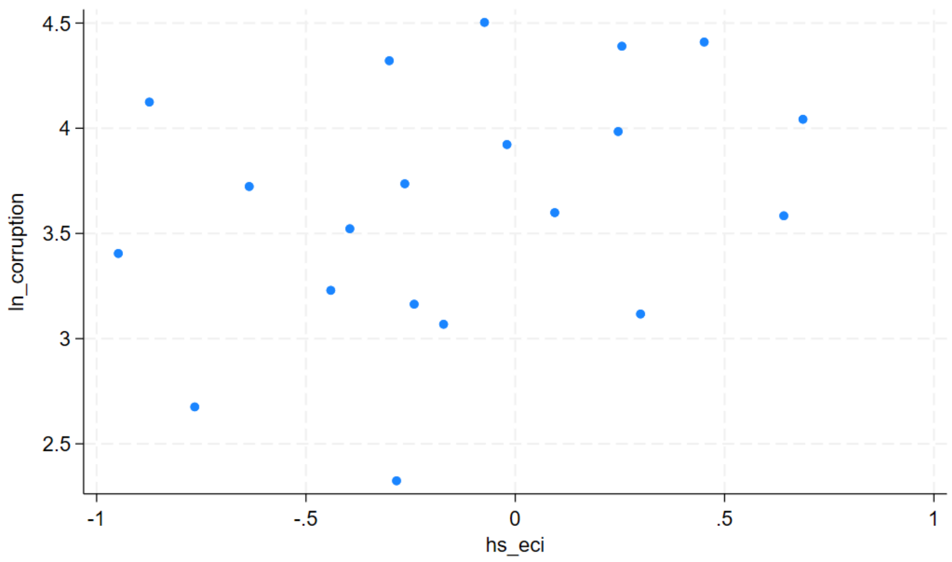
Note: The sample size of N=20 requires higher t-statistic values. Our preferred measure for natural resources is NRA.

Table 6 reports all different combinations of natural resource richness measurements interacted with either ECI or control of corruption (recall, high values indicate good corruption control). Overall, we find that though interacted with the initial level of Economic Complexity, neither of our measures for natural resource richness is indicating to promote long-term economic growth.

We also report the results for the above estimations controlling for human capital or initial GDP per capita in appendix A.3. Interestingly, we find that initial GDP per capita enters the equation positive and significant, indicating divergence between the countries over the last 25 years. The conditional effect of NRA on growth remains negative in all combinations.

Lastly, figure 9 shows the association between ECI and corruption control.

Figure 8: Association between corruption control and growth9519



Note: Own calculation.

6 Conclusion

A) In the chapter about theory and previous research I made clear what Economic Complexity is and how it differs from economic growth (GDP per capita). We have seen that the ECI conceptually captures all different kinds of productive capabilities but that the indicators focus on productive knowledge because we use the ordering of the HS or SITC system. We have also presented several factors (inequality and taxation) that potentially affect both, institutional quality and Economic Complexity but both of these factors are also linked to typical natural resource curse mechanisms and thus, NRA can potentially have a detrimental effect on institutional quality and Economic Complexity via inequality and taxation at the same time.

B) Our empirical result contradicts the previous findings of the mediating role of Economic Complexity within resource-growth equations. Even though we find that NRA tends to have a negative effect on long-term growth, this effect remains negative when we interact it with the ECI.

Finally, for Latin American countries we do not find that the initial level of Economic Complexity is having a positive effect on long-term growth at all.

References

Avom, D., Keneck-Massil, J., Njangang, H., & Nvuh-Njoya, Y. (2022). Why are some resource-rich countries more sophisticated than others? The role of the regime type and political ideology. Resources Policy, 79, 103067.

Badeeb, R. A., Lean, H. H., & Clark, J. (2017). The evolution of the natural resource curse thesis: A critical literature survey. Resources Policy, 51, 123-134.

Barro, R. J. (1991). Economic growth in a cross section of countries. The quarterly journal of economics, 106(2), 407-443.

Brunnschweiler, C. N., & Bulte, E. H. (2008). The resource curse revisited and revised: A tale of paradoxes and red herrings. Journal of environmental economics and management, 55(3), 248-264.

Cadot, O., Carrère, C., & Strauss-Kahn, V. (2013). Trade diversification, income, and growth: what do we know?. Journal of Economic Surveys, 27(4), 790-812.

Collier, P., & Goderis, B. (2008). Commodity Prices, Growth, and the Natural Resource Curse: Reconciling a Conundrum. https://doi.org/10.2139/ssrn.1473716

Corden, W. M., & Neary, J. P. (1982). Booming sector and de-industrialisation in a small open economy. The economic journal, 92(368), 825-848.

Davis, G. A., & Tilton, J. E. (2005). The resource curse. Natural Resources Forum, 29(3), 233–242. https://doi.org/10.1111/j.1477-8947.2005.00133.

Deacon, R. T. & Rode, A. (2015). Rent seeking and the resource curse. In Companion to the Political Economy of Rent Seeking (pp. 227–247). Edward Elgar Publishing.

Engerman, S. L., & Sokoloff, K. L. (2002). Factor endowments, inequality, and paths of development among new world economics. Economic Journal of the Latin American and Caribbean Economic Association.

Feenstra, R., & Kee, H. L. (2008). Export variety and country productivity: Estimating the monopolistic competition model with endogenous productivity. Journal of international Economics, 74(2), 500-518.

Frankel, J. A. (2010). The natural resource curse: a survey (No. w15836). National Bureau of Economic Research.

Gouvea, R., & Vora, G. (2015). Reassessing Export Diversification Strategies: A Cross-Country Comparison. Modern Economy, 06(01), 96–118. https://doi.org/10.4236/me.2015.61009.

Gräbner, C., Heimberger, P., & Kapeller, J. (2020). Do the" smart kids" catch up? Technological capabilities, globalisation and economic growth (No. 9). ifso working paper.

Gylfason, T. (2001). Natural resources, education, and economic development. European economic review, 45(4-6), 847-859.

Gylfason, T. (2006). Natural resources and economic growth: From dependence to diversification. Economic liberalization and integration policy: Options for Eastern Europe and Russia, 201-231.

Haber, S., & Menaldo, V. (2011). Do natural resources fuel authoritarianism? A reappraisal of the resource curse. American political science Review, 105(1), 1-26.

Haber, S., & Menaldo, V. (2012). Natural resources in Latin America: neither curse nor blessing.

Hartmann, D., Guevara, M. R., Jara-Figueroa, C., Aristarán, M., & Hidalgo, C. A. (2017). Linking economic complexity, institutions, and income inequality. World development, 93, 75-93.

Hausmann, R., & Hidalgo, C. A. (2011). The network structure of economic output. Journal of economic growth, 16, 309-342.

Hausmann, R., Hidalgo, C. A., Bustos, S., Coscia, M., & Simoes, A. (2014). The atlas of economic complexity: Mapping paths to prosperity. Mit Press.

Hidalgo, C. A., Klinger, B., Barabási, A. L., & Hausmann, R. (2007). The product space conditions the development of nations. Science, 317(5837), 482-487.

Hidalgo, C. A., & Hausmann, R. (2009). The building blocks of economic complexity. Proceedings of the national academy of sciences, 106(26), 10570-10575.

Hidalgo C. A. (2015). Why Information Grows. The Evolution of Order, from Atoms to Economies, Basic Books, New York, NY.

Hidalgo, C. A. (2021). Economic complexity theory and applications. Nature Reviews Physics, 3(2), 92-113.

James, A. (2015). The resource curse: A statistical mirage?. Journal of Development Economics, 114, 55-63.

Klinger, B., & Lederman, D. (2006). Diversification, innovation, and imitation inside the global technological frontier. World Bank policy research working paper, (3872).

Lashitew, A. A., & Werker, E. (2020). Do natural resources help or hinder development? Resource abundance, dependence, and the role of institutions. Resource and Energy Economics, 61, 101183.

Lashitew, A. A., Ross, M. L., & Werker, E. (2021). What drives successful economic diversification in resource-rich countries?. The World Bank Research Observer, 36(2), 164-196.

Maurya, G., & Sahu, S. (2022). Cross-country variations in economic complexity: The role of individualism. Economic Modelling, 115, 105961.

Mesagan, E. P., & Vo, X. V. (2023). The Importance of economic complexity in the resource-growth discourse: Empirical evidence from Africa. Journal of the Knowledge Economy, 1-22.

Michaely, M. (1958). Concentration of exports and imports: an international comparison. The Economic Journal, 68(272), 722-736.

North, D. C. (1994). Economic performance through time. The American economic review, 84(3), 359-368.

Papyrakis, E., & Pellegrini, L. (2019). The resource curse in Latin America. In Oxford Research Encyclopedia of Politics.

Ramez, B., Lean, H., & Clark, J. (2016). The evolution of the natural resource curse thesis: a critical literature survey. Working Paper-Department of Economics and Finance, University of Canterbury, (05/2016).

Romer, P. M. (1986). Increasing returns and long-run growth. Journal of political economy, 94(5), 1002-1037.

Ross, M. L. (1999). The Political Economy of the Resource Curse. World Politics, 51(2), 297–322. https://doi.org/10.1017/s0043887100008200

Ross, M. L. (2015). What have we learned about the resource curse?. Annual review of political science, 18, 239-259.

Sachs, J. D., & Warner, A. (1995). Natural resource abundance and economic growth.

Sachs, J. D., & Warner, A. M. (1997). Sources of slow growth in African economies. Journal of African economies, 6(3), 335-376.

Tabash, M. I., Mesagan, E. P., & Farooq, U. (2022). Dynamic linkage between natural resources, economic complexity, and economic growth: Empirical evidence from Africa. Resources Policy, 78, 102865.

Torvik, R. (2009). Why do some resource-abundant countries succeed while others do not?. Oxford review of economic policy, 25(2), 241-256.

van Wijnbergen, S. (1984). The `Dutch Disease': A Disease After All? The Economic Journal, 94(373), 41. https://doi.org/10.2307/2232214

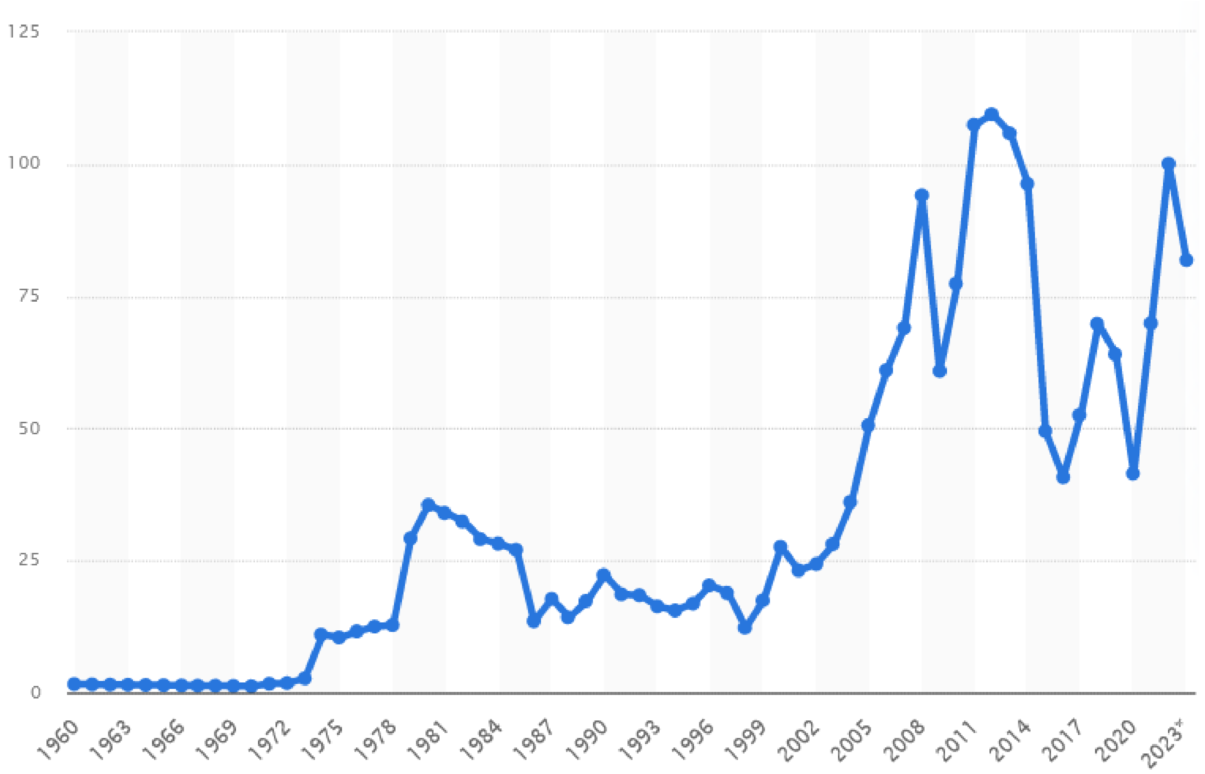
Appendix A

Appendix A.1: Correlation matrix of 2019 ECI, GDP per capita and Population

	hs_eci	rgdppc19	pop
hs_eci	1.0000		
rgdppc19	0.6163	1.0000	
pop	0.3761	0.0470	1.0000

Source: Own calculation.

Appendix A.2: Average annual OPEC crude oil price (in US$ per barrel) from 1960 to 2023.



Source: Extracted from https://www.statista.com/statistics/262858/change-in-opec-crude-oil-prices-since-1960/ (12.12.2023).

Appendix A.3: Robustness tests

```
reg growth9519 initgdppc ECI_NRA

      Source |       SS           df       MS      Number of obs   =        20
-------------+----------------------------------   F(2, 17)        =      3.22
       Model |  20.8480342         2  10.4240171   Prob > F        =    0.0651
    Residual |  55.0094212        17   3.2358483   R-squared       =    0.2748
-------------+----------------------------------   Adj R-squared   =    0.1895
       Total |  75.8574554        19  3.99249765   Root MSE        =    1.7988

------------------------------------------------------------------------------
  growth9519 | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
   initgdppc |   1.276248    .508334     2.51   0.022     .2037573    2.348739
     ECI_NRA |  -.1217293   .1813789    -0.67   0.511    -.5044054    .2609467
       _cons |  -4.652682   4.413527    -1.05   0.307    -13.96441    4.659046
------------------------------------------------------------------------------
```

```
. reg growth9519 hc ECI_NRA

      Source |       SS           df       MS      Number of obs   =        20
-------------+----------------------------------   F(2, 17)        =      0.81
       Model |  6.61194691         2  3.30597345   Prob > F        =    0.4606
    Residual |  69.2455085        17  4.07326521   R-squared       =    0.0872
-------------+----------------------------------   Adj R-squared   =   -0.0202
       Total |  75.8574554        19  3.99249765   Root MSE        =    2.0182

------------------------------------------------------------------------------
  growth9519 | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
          hc |   1.757713   1.429246     1.23   0.236    -1.257732    4.773159
     ECI_NRA |  -.0418913   .2030881    -0.21   0.839    -.4703697    .3865871
       _cons |   2.519031   3.173281     0.79   0.438    -4.176008    9.214069
------------------------------------------------------------------------------
```