The resource curse reloaded: revisiting the Dutch disease with economic complexity analysis

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Abstract
This paper shows that the Dutch disease can be more formally characterised as low economic complexity using ECI-type indicators; there is a solid and robust inverse relationship between exports concentrating on natural resources and economic complexity as measured by complexity indicators for a database of 122 countries from 1963 to 2013. In a large majority of cases, oil answers for shares in excess of 50% of exports. In addition to empirical panel analysis, we address case studies concerned with Indonesia and Nigeria and introduce a brief review of the theoretical literature on the topic. Indonesia is considered in the literature as a good example in avoiding the negative effects of the Dutch disease, whereas Nigeria is taken as a bad example in terms of institutions and policies adopted during the seventies and eighties. The empirical results show that complexity analysis and Big Data may offer significant contributions to the still-current debate surrounding the Dutch disease.

JEL codes O1, O14, C1, F20, F41, F43, O57, Q32

Keywords Dutch disease, economic complexity, economic development

Introduction

The term "Dutch disease" was coined to describe the problems that emerged in the Netherlands in the 1960s and 1970s after the discovery of gas reserves. The sudden increase in exports of this product caused important changes for the Dutch economy. The excessive currency appreciation arising from the income that the new discovery generated implied a retraction for the Dutch manufactured goods industry, which ultimately led to unemployment and lower growth rates. The country's economic situation worsened after the reserves' discovery, in a paradox that became known as the "Dutch disease" problem, or the resource curse. The literature analyses many more such cases. Some authors showed how the discovery of gold in Australia in the 19th century caused similar problems for manufacturing in that country, or how the strong influx of gold into Spain in the 1500s as a result of discoveries in the Americas was also harmful. More generally, the Dutch disease paradoxically connects with the negative effects of the economic rents generated by great discoveries or the abundance of natural resources such as gold, oil, and gas.

This paper shows that the Dutch disease can be more formally characterised as low economic complexity with the use of ECI-type indicators; a solid and robust inverse relationship exists between exports that concentrate natural resources and economic complexity as measured by ECI indicators. In a large majority of cases, oil accounts for more than 50% of exports. The article is divided into five sections. Section one reviews the importance of manufacturing as an economy's productivity generator and analyses how the Dutch disease literature addresses this issue. Section two introduces the concept of economic complexity and analyses the main characteristics of the manufacturing sector and of the production of natural resources based on this new conceptual view. The third section is concerned with case studies for Nigeria and Indonesia. The fourth section uses panel data to empirically analyse 122 countries from 1963 to 2013. The paper's fifth section summarises our conclusions.

1. Theoretical aspects of the Dutch disease

The theoretical arguments that explain the channels by means of which the Dutch disease may affect an economy essentially relate to the reduction of the manufacturing sector. The currency appreciation that arises from the export of natural resources hampers the production of agricultural tradables and, in particular, manufactured ones that carry greater potential for technological innovations and productivity gains. The natural resources sector crowds out agricultural and manufacturing production. Capital and labour shift to natural-resource extraction and non-tradables production. The country's manufacturing sector turns inwards, specialising in the production of non-tradables with better returns because of the appreciated currency. Depending on the intensity of the process, the economy becomes "inward-looking", which also harms its efficiency level because of the absence of the competition it would face in the world market (Bresser-Pereira, 2007).

The models describing Dutch disease problems assume an economy with three sectors: non-tradables (NT), tradable natural resources such as oil (RT), and agricultural and manufactured tradables (MT). Corden (1984) analyses the issue in terms of a non-tradables sector (NT), a "booming sector" (B), and a "lagging sector" (L), where B represents the tradable natural resources sector and L stands for the manufactured exports sector. According to these models' traditional rationale, expansion of the natural resources sector (RT) causes exchange appreciation via two possible channels: increased flow of funds as a result of rising exports and increased prices of non-tradables because of the rising domestic demand stemming from the income gains in the natural resources sector. The manufactured tradables sector (MT) suffers because it loses capital and labour which shift to the non-tradables (NT) and natural resources (RT) sectors.

These consequences may also be described in terms of two effects: a resources shift, where capital and labour transfer to the "booming" sector because of increased returns, and the expenditure effect, according to which the factors used in the "non-booming" tradables sector also transfer to non-tradables because of increased demand. The latter effect's highlight lies in the increased demand for non-tradables as a result of the rising income that the booming sector generates. Agricultural and manufactured tradables then start being imported. By the end of a process with these characteristics, the non-tradables and natural resources sectors will have expanded, and the non-traditional tradables sector, manufacturing in particular, will have shrunk (Gelb, 1988).

On the problem of deindustrialisation in association with the Dutch disease, Palma (2003) points out the unemployment present in such cases. A pattern of manufacturing job decreases emerges in connection with a development process that naturally shifts workers from manufacturing to services industries. The negative effects of excessive currency appreciation stemming from the funds inflow generated by the commodities and tourism services sectors cause a premature eviction of workers from manufacturing. This splits countries into two categories: those that pursue an external surplus in the manufacturing sector because of a need to import other types of goods and those that pursue a strategy of industrialisation and manufactured goods exports despite being rich in natural resources. The author analyses the path of several countries that navigated the problem of the Dutch disease, particular note being due to Southeast Asian ones. Malaysia, Indonesia, and Thailand are illustrative of what Palma (2003) calls "swimming against the tide" of deindustrialisation. Despite the presence of vast natural resources, they have been able to develop significant manufacturing industries.

The negative effect of the Dutch disease therefore relates to blocking the development of a non-traditional agricultural or manufactured tradables goods sector as a result of exchangev rate appreciation (Bresser-Pereira, 2007). Assuming positive externalities, "learning by doing" (Wijnbergen, 1984), or forward and backward linkages *à la* Hirshman in the production of such goods, the absence or retraction of such a sector has severe consequences in terms of technological dynamics and productivity gains. The agricultural and manufacture tradables sector's retraction causes – possibly irreversible – losses of knowhow, local capabilities, and production plants. The literature also refers to this outcome as the effect of the loss of technological spillovers due to the Dutch disease (see also Williamson 2005, 2003 and Sachs and Warner, 1995). As van Wijnbergen (1984) argues, economic development success cases after World War Two, without exception, involve aggressive promotion of the tradables sector, where technological progress is faster.

2. The Dutch disease defined as a loss of economic complexity

Empirically, it has never been easy to determine whether a country is experiencing or has experienced the Dutch disease. Great steps in this direction are possible with the use of the *Atlas of Economic Complexity*. Based on the *Atlas's* measures, one may more accurately define the Dutch disease in empirical terms: loss of economic complexity or a drop in the ECI indicator. The benefits of using the complexity index (ECI) to measure the Dutch disease lie in comparability and the availability of data for the past 50 years. Hausmann *et al* (2011) use computing, networks, and complexity techniques to create an extraordinarily simple method capable of measuring countries' productive sophistication, or "economic complexity". Based on the analysis of a country's exports, they can indirectly measure the technological sophistication of its productive tissue. The method created to build economic complexity indices culminated in an *Atlas* (http://atlas.media.mit.edu) that collects extensive material on countless products and countries since 1963. How does one measure an economy's "complexity"?

The two basic concepts for measuring a country's economic complexity, or sophistication, are the ubiquity and diversity of the products it exports. If a certain economy is capable of producing non-ubiquitous goods, this indicates a sophisticated productive tissue. Naturally, a problem of relative scarcity exists here, particularly for natural goods such as diamonds and uranium, for example. Non-ubiquitous goods must be divided into those with high technology content, which are therefore difficult to produce (airplanes, for example) and those that are highly scarce in nature (niobium, for example), which are therefore naturally non-ubiquitous. To control for the problem that scarce natural resources pose for measuring complexity, Hausmann *et al* (2011) use an ingenious technique: they compare the ubiquity of a good made in a certain country with the diversity of goods that other countries that also make the same good can export. For example, Botswana and Sierra Leone produce and export something that is rare and, therefore, non-ubiquitous: uncut diamonds. However, their exports are extremely limited and undiversified. These, then, are cases of non-ubiquity without complexity.

At the opposite end lie, for example, products such as medical imaging equipment, which practically only Japan, Germany, and the United States can manufacture; they are clearly non-ubiquitous. In this case, however, the exports of Japan, the United States, and Germany are extremely diversified, indicating that these countries are capable of making many different things. That is, non-ubiquity with diversity means "economic complexity". In contrast, a country with very diversified but ubiquitous exports (fish, fabrics, meat, ores, etc.) does not show great economic complexity; the country makes what every country makes. Diversity with ubiquity means a lack of economic complexity. The authors' trick with their complexity measures is to use diversity to control for ubiquity and vice-versa. The Netherlands, for example, is considered complex because its exports are diversified and non-ubiquitous; it is one of the few countries in the world to export X-ray machines. Ghana, in contrast, is a non-complex country because its exports lack diversity and cover ubiquitous products: fish and agricultural goods. Argentina lies at an intermediate position, with more diversified and less ubiquitous exports than Ghana but less diversified and more ubiquitous ones than the Netherlands'; it is therefore regarded as of intermediate complexity. The *Atlas*'s complexity calculation routine turns these important differences into a number called economic complexity that applies to both countries (ECI) and products (PCI). For example, in 2014, Pakistan's economic complexity was -.75 and Singapore's was 1.40, meaning that the latter was more complex than the former in that year.

One of the main virtues of these complexity indicators is that they rely on quantitative measures based on linear algebra calculations to arrive at results. They do not consider qualitative issues relevant to producing and exporting such goods. That is, they do not pass judgment on the complexity or non-complexity of products. Another interesting benefit lies in the measures' power to coherently capture huge changes in production technologies over time. A TV set from the 1970s is entirely different from another made in 2014. A car, airplane, or motorcycle from the 1980s is far from what we now call a car, motorcycle, or airplane. But, even so, the *Atlas*' methodology can capture the relative difficulty of producing each good at any point in time. A country now capable of producing a motorcycle may have been unable to do so in 1980 due simply to the fact that with today's technologies and trade integration it is far easier to make a motorcycle. But, for the purposes of the *Atlas*, a motorcycle is probably far less sophisticated today than it was in 1980. The concept of complexity remains over time a relative measure across countries and goods. Along these lines, Hausmann *et al* (2011) classify countries to arrive at impressive correlations between per-capita income levels, growth and economic complexity; this indicator may be used as proxy for the relative economic development across countries. It is no accident that Japan, Germany, the United States, the United Kingdom, and Sweden have always been among the world's most complex countries over the past 20 years.

The *Atlas of Economic Complexity* makes a very interesting contribution to the discussion of the Dutch disease; from the angle of a strictly empirical analysis based on the *Atlas*'s algorithm, manufactured goods are clearly characterised as more complex goods and commodities as less complex ones. By calculating the probability of products being co-exported by several countries, the *Atlas* creates an interesting measure of the productive knowhow contained in the products and of the local capabilities needed for their production: the "productive space" (Hidalgo *et al,* 2007). The greater the probability of two products being co-exported, the greater the indication that they contain similar characteristics and, therefore, require similar productive capabilities for production; they are "sibling" or "cousin" products. The co-exportation indicator ultimately serves as a measure of the productive knowhow linkage between products. That is, it indicates the productive "connections" between several goods that emerge from their shared production requirements. Goods with high "connectivity" are therefore loaded with potential for technological knowhow. This makes them "knowledge hubs", whereas goods with low connectivity require simple productive capabilities, with low potential for knowhow multiplication.

For example, countries that make advanced combustion engines probably have engineers and knowledge that enable them to make a series of other similar and sophisticated products. Countries that only produce bananas or other fruits have limited knowhow and are probably incapable of producing more complex goods. It is important to emphasise that the difficulty observing this stems from the inability to directly measure and capture these local productive skills. International trade shows products, not the countries' ability to produce them. Empirically, the *Atlas* shows that manufactured goods are generally characterised as more "connected" and complex goods, and commodities emerge as less complex and "connected". Out of the 34 main communities of products calculated based on a compression algorithm from the *Atlas* (Rosvall and Bergstrom, 2007), machinery, chemicals, airplanes, ships, and electronics stand out as more complex and "connected" goods (that is, knowledge hubs). In contrast, precious stones, oil, minerals, fish and shellfish, fruits, flowers, and tropical agriculture show very low complexity and connectivity. Grains, textiles, construction equipment, and processed foods lie at an intermediate position between more and less complex and connected goods.

As for criticism of and potential problems with the complexity analysis methodology, its main fault may perhaps be to rely solely on export data as proxies for the productive structures of the various countries. This is indeed a weakness, as it is a known fact that, for a number of reasons, many countries produce but do not export some goods. The entire analysis is based on what can be "seen" from world trade data: a broad, disaggregated, standardised base that extends from the 1960s. The main benefit of these trade databases lies precisely in the standardisation, capillarity, and longevity of the data; its disadvantage lies in not capturing each country's domestic idiosyncrasies. In contrast, the national accounts databases that might contain such data do not, at this time, capture the same type of information at the level of granularity needed for the kind of analysis done here; they usually have few productive disaggregation layers. Another issue with the methodology is that it does not identify "maquila" countries: those that merely import and then export complex products, Mexico being the notorious case. Regarding this issue, Schteingart (2014) does an interesting job qualifying countries' "genuine" complexity by taking into account the number of patents filed and R&D expenditures as a percentage of GDP.

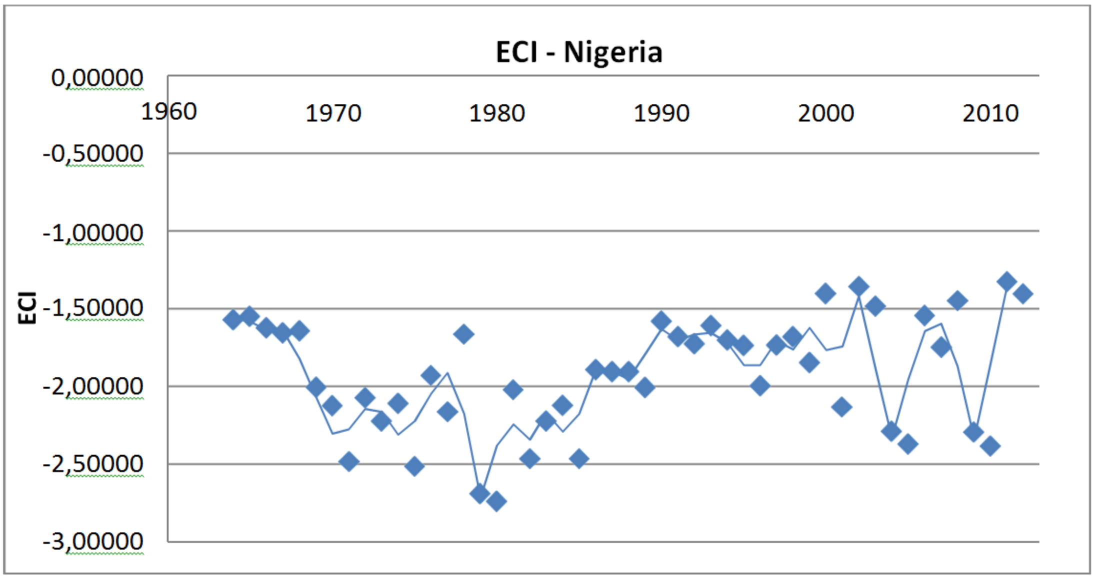
3. Cases of Dutch disease and complexity dynamics: Indonesia and Nigeria

In one of the most relevant references in the literature, Gelb (1988) discusses the case of countries that experienced the disease in the 1980s because of large oil reserves. He analyses the results of the oil shock for six economies with an abundance of this resource: Indonesia, Algeria, Ecuador, Nigeria, Trinidad and Tobago, and Venezuela. The author builds a single index capable of measuring the effects of the Dutch disease in each of these economies based on the evolution of their non-oil tradables sectors after the shocks. Nigeria and Trinidad and Tobago show the worst outcomes, with high currency appreciation in 1974-1978 through to 1984. Algeria, Venezuela, Indonesia, and Ecuador show better outcomes. The former three were able to keep their non-oil tradables sectors relatively unscathed during the period, although its representativeness in Algeria and Venezuela had always been very small. The highlight in the sample is Indonesia, which was able to use currency devaluations to maintain the dynamism of its non-oil tradables sector (Gelb 1988).

In the Nigerian case, funds from the vast oil reserves were misused and ended up harming the country's growth path. Oil was found in 1956 and exports for the world market began in 1958. By the 1970s, 50% of Nigeria's exports came from oil, although agriculture remained the main activity, at 40% of non-oil GDP and 70% of the workforce. By the late 1970s, non-oil exports had all but vanished because of the price shock. The oil sector grew from 1% of GDP in the 1960s to 25% in the 1970s, and by 1979, oil accounted for 90% of the country's total exports. The agriculture sector retracted markedly, while the government concentrated funds from oil revenues in the non-tradables sector, which was extremely poor at the time (Gelb, 1988).

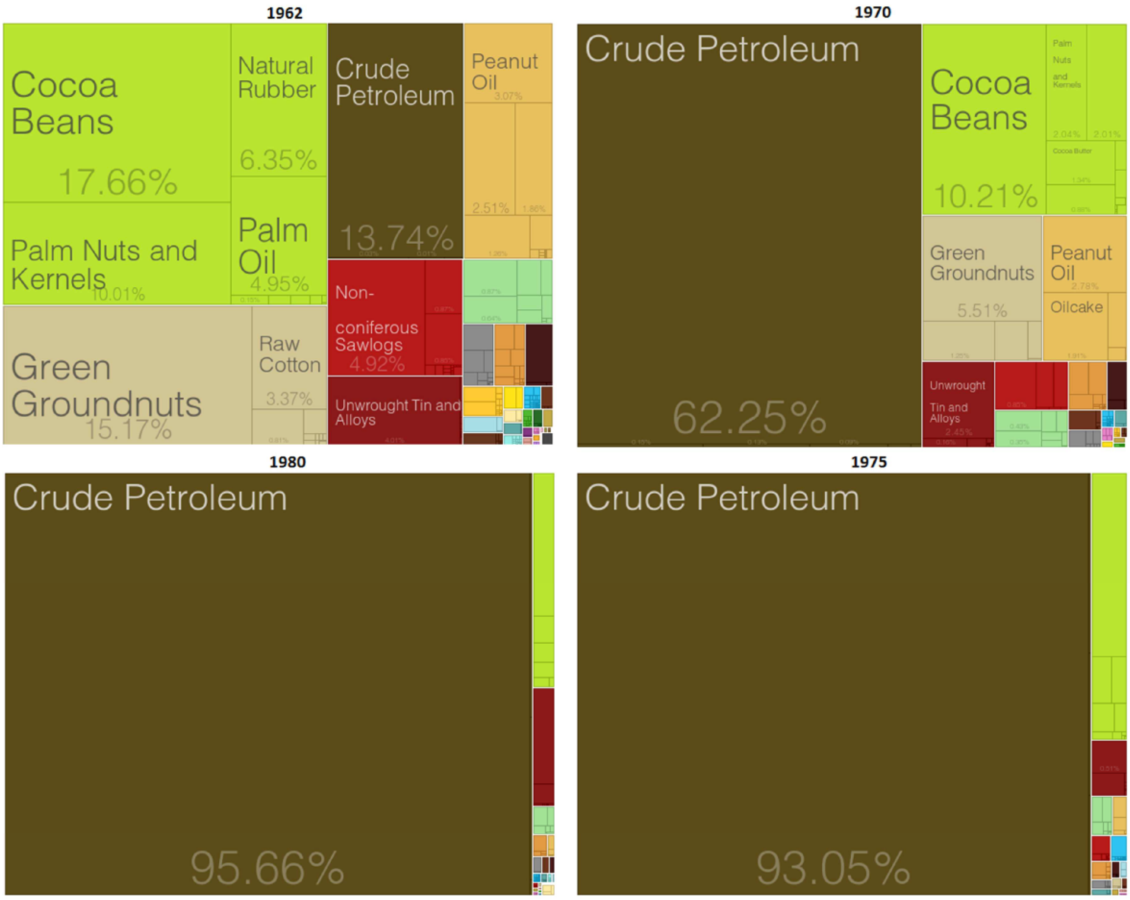
Over the course of the two oil shocks, the Nigerian real exchange rate appreciated intensely. The increased domestic demand generated by the rising revenues from oil exports led to a persistent rise in inflation during the 1970s. Because of import restrictions and inelastic food product supply, prices rose rapidly. The nominal exchange rate, pegged as it was to a basket of currencies of trade partners, together with annual inflation rates of around 20% from 1973 and 1978, led to an extremely appreciated real exchange rate. According to Gelb's (1988) calculations, the real exchange rate went from an average 100 in 1970-1972 to 287 in 1984. The Nigerian government's response was primarily to increase import tariffs in an effort to protect domestic manufacturing. By the mid-1970s, non-oil exports were practically insignificant, dropping in 1982 to one-seventh of their 1973 value. Nigeria became a net importer of agricultural goods in 1975. The country's total imports rose sharply in 1975-1978 and 1980-1982, with a massive loss of technological sophistication compared to the 1960s, as illustrated by the economic complexity index (ECI) and the export maps below.

Figure 1 Economic complexity in Nigeria



Source: elaborated by authors with data from the Atlas of Economic complexity: http://atlas.media.mit.edu/en/

Figure 2 Exports of Nigeria

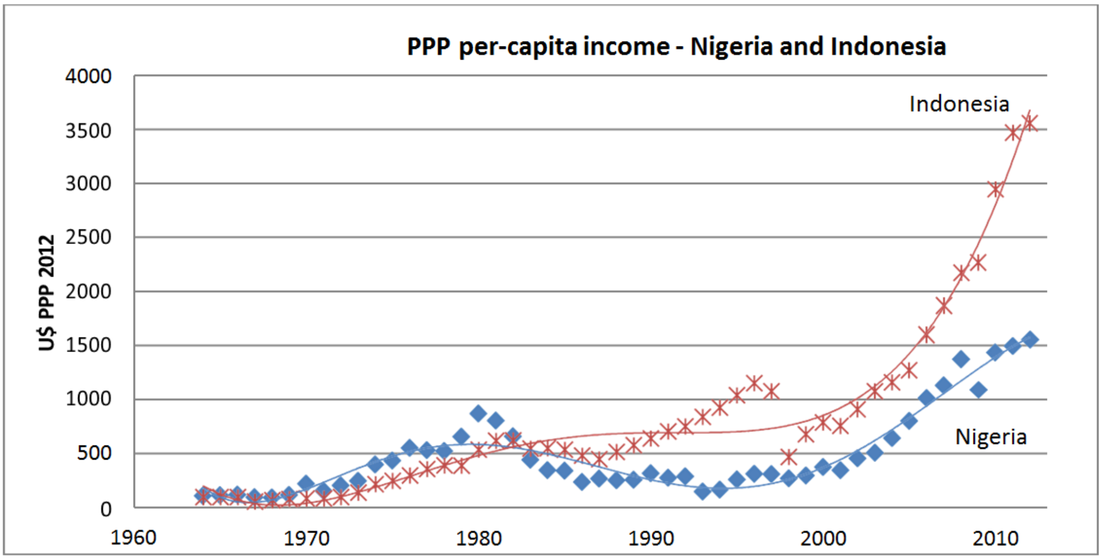


Source: elaborated by authors with data from the Atlas of Economic complexity: http://atlas.media.mit.edu/en/

An important contrasting case relative to Nigeria's is Indonesia, which is equally rich in oil but was able to manage its resources more rationally. It developed a dynamic agricultural and manufactured export tradables sector in parallel with the oil industry. Unlike Indonesia, where oil funds were also used to invest in agriculture, which prospered during and after the shock, the agricultural sector collapsed in Nigeria. The exchange rate appreciation caused by the rising domestic prices was intense, and the government took no steps to realign the real exchange rate. Productive activities were mostly redirected to the production of oil instead of tradables.

Despite the abundance of natural resources such as oil, rubber, and lumber, Indonesia was one of the poorest and most populated countries in the world in the 1970s, with a per-capita GDP of U$715 (1985 US dollars) and 129 million inhabitants. The team of bureaucrats that took over with Suharto's coup launched a successful economic action plan with the following guidelines: stabilising the economy, strengthening agriculture, manufacturing, and infrastructure, fostering foreign trade and exports, fiscal austerity, and reforming the financial industry. Among the specific measures taken, we emphasise the 1970 unification of the foreign exchange market, with the subsequent devaluation of the rupiah and the adoption of a pegged exchange regime starting in 1971. By the early 1970s, certain indices already reflected the plan's positive effects: inflation below 10% annually, rising agricultural and manufacturing production, and an increase in currency reserves. Tax revenues rose from 4% of GDP in 965 to 10% in 1970.

Figure 3 Complexity and per capita income in Nigeria and Indonesia



Source: elaborated by authors with data from the Atlas of Economic complexity: http://atlas.media.mit.edu/en/

Before the first oil shock, a huge crisis abated over Pertamina, Indonesia's biggest state oil company. Because of excessive debt with no central-government control, the company was unable to honour its obligations in 1974. To navigate the crisis, the government was forced to redirect two-fifths of all annual national oil revenues to pay the company's debt. The massive negative consequences of the event for Indonesia's economy taught the government a lesson about the potential risks of excessive economic dependence on oil. The Pertamina case strongly influenced the country's response to the oil shocks. In the md-1970s, the fixed exchange rate regime, associated with an inflation spike stemming from a failed food product harvest and the rising income and demand because of the positive oil-price shock led to a marked appreciation of Indonesia's real exchange rate. According to Gelb's (1988) calculations, the real exchange rate rose from a 100-base in 1970-1972 to 133 in 1978. The government responded with fiscal controls and monetary restrictions. That same year, authorities devalued the rupiah from 415 to 625 per US dollar. Many analysts (World Bank, 1993; Edwards, 1991; and Hill 2000, for example) emphasised that this devaluation was not associated with balance-of-payments problems or trouble paying for imports as oil revenues continued to flow into the country. Gelb (1988) argued that the authorities' purpose was to protect the non-oil tradables sector, in particular rubber, coffee, and the nascent manufactured goods industry. The public revenue gains stemming from the rise in oil prices in 1973 and 1974 were largely used to invest in infrastructure, agriculture, and manufacturing.

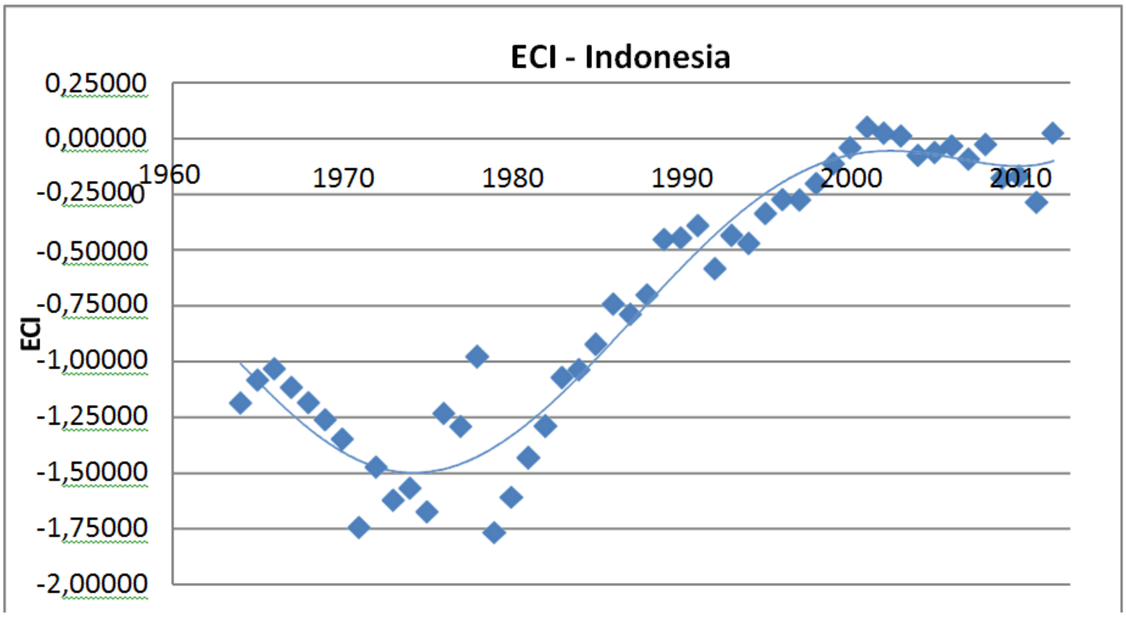
For the second oil shock, the authorities' response was also quite positive. They maintained a reasonably balanced fiscal position, even achieving surpluses at times. In terms of foreign accounts, Indonesia went from a current-account deficit of 1.6% of GDP (except mining activities) to a 2.3% surplus in the late 1970s. Currency reserves rose from 2.6 billion US dollarsin 1978 to 5 billion in 1980, despite high foreign debt. Compared with five similar cases analysed in Gelb (1988) – Ecuador, Nigeria, Venezuela, Algeria, and Trinidad and Tobago – Indonesia's real exchange rate remained practically stable in 1978-1982, showing almost no real appreciation (Gelb, 1988). With the drop in oil prices seen in the early 1980s and markedly deteriorating foreign accounts, the government again devalued the rupiah to 970 on the US dollar in 1983.

Throughout the 1980s, the exchange policy strategy continued, with a new devaluation of the rupiah in 1986 in response to the dropping oil prices and the adoption of a crawling peg system until the early 1990s. At first, the exchange rate followed the path of the US dollar, which devalued after the Plaza Accord, particularly against the yen. With the stabilisation of the US currency and moves toward appreciation in the early 1990s, Indonesia's authorities introduced a wider crawling peg, letting the rupee again devalue against a basket of currencies. Indonesia's performance was most remarkable in non-traditional exports. From 1982 to 1992, non-oil exports rose by 300%. In 1979, after the first devaluation, manufactured goods exports increased by 260%. A similar behaviour occurred after the 1983 devaluation (Gelb, 1988). The marked increase in manufactured goods exports was among the main factors responsible for keeping the economy on a positive path after the marked drop in oil prices in the mid-1980s. One of the sectors that prospered the most then was manufactured goods. Exports-oriented foreign direct investment started to flow into the country vigorously in 1986. Some authors mention an Indonesian exports boom after 1985 (see Hill, 2000). In terms of exports breakdown, the change is quite remarkable. In 1980, manufactured goods accounted for 3% of Indonesia's exports. The share rose to 7% in 1983 and reached 50% in 1992. However, despite the importance of exports in transforming the economy's structure, one cannot properly say that the country followed an export-led growth path like its Asian neighbours. Until the early 1990s, Indonesia's exports had never exceeded 31% of GDP. A series of preventive measures, including proper foreign exchange rate policy, made Indonesia an important case of overcoming the Dutch disease, as seen in the exports and economic complexity (ECI) maps below.

Figure 4 Exports of Indonesia

Source: elaborated by authors with data from the Atlas of Economic complexity: http://atlas.media.mit.edu/en/

Figure 5 Economic complexity in Indonesia

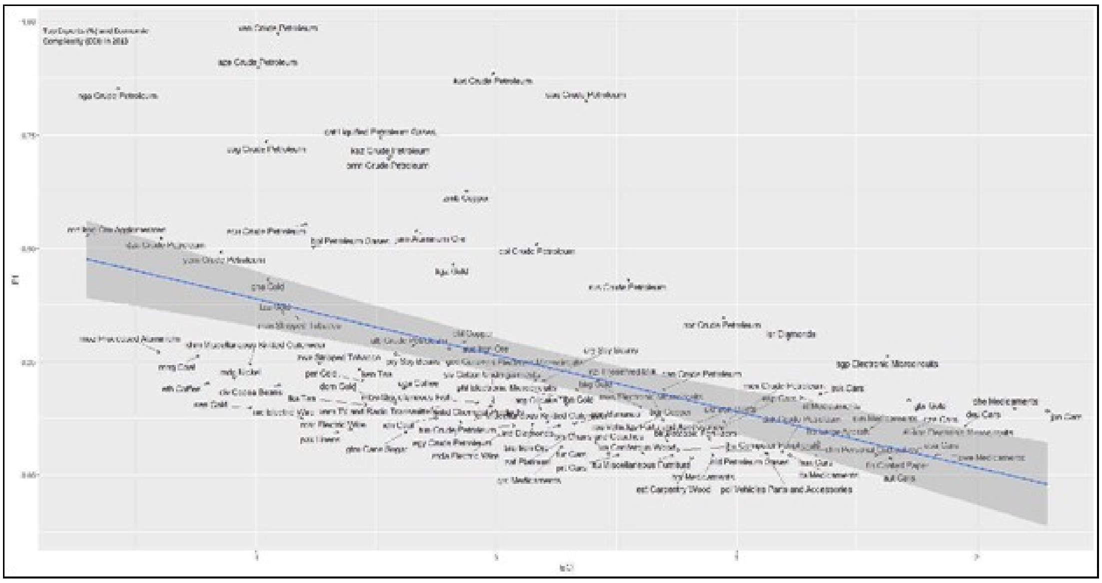


Source: elaborated by authors with data from the Atlas of Economic complexity: http://atlas.media.mit.edu/en/

4. Panel analysis

In this section, we set up a panel of 12 four-year periods (1965 to 2013) and 122 countries with distinct export structures to evaluate the impact of concentrating exports on the change in the Economic Complexity Index (ECI). A high share of a good in total exports is understood as a symptom of the Dutch disease and reduced complexity is one of its harmful consequences for economic development, as discussed previously. Our analysis here attempts to evaluate these ideas in broader empirical terms. Our database has 5,108,305 lines covering the years 1963 to 2013, and the information includes the SITC-4 codes for the exported products, the origin and complexity of the exports, and the amount of exports in US dollars for each country in each year. The complete data bank covers 250 countries and 986 different products. To calculate the panel regressions, the data were treated and filtered using a routine to capture the top two products out of all exports. The graph next summarises the 2013 data with economic complexity on the X-axis and the share of the main exported product on the Y-axis.

Figure 6 Main exports of selected countries in 2013



Source: elaborated by authors with data from the Atlas of Economic complexity: http://atlas.media.mit.edu/en/

The economic complexity indexes for 1965-2013 have been obtained from the *Atlas of Economic Complexity* (Hausmann et al, 2011), and the control variables used in the regressions were drawn from the Penn World Table 9.0 (Fenestra et al., 2015). The selected econometric method was System GMM (Blundel and Bond, 1998). The estimator was developed based on the Arellano-Bond (1991) GMM estimator, which takes into consideration two sources of persistence over time: autocorrelation arising from the inclusion of lagged variables and individual effects to control for heterogeneity among individuals. With these estimators, the orthogonality between the time-lagged variables and the disturbances generate additional instruments. The difference between the Arellano-Bond GMM estimator and System GMM is that the latter enables causal analysis without the need for additional

exogenous instrumental variables, as it relies on lagged variables as instruments for the level equations and level variables as instruments for the lagged variables.
The impact of export concentration on the change in economic complexity is estimated based on the following equation:

$$dECI_{i,t} = \alpha\, dECI_{i,t-1} + \beta\, top\_pr_{i,t} + \gamma\, Z_{i,t} + a_i + \mu_{i,t} \quad (1),$$

where $dECI$ is the change in the economic complexity index, top_pr is the share of the country's top export product, and Z is the set of control variables. The long-term impact of export concentration in economic complexity increase is therefore given by

$$b = \beta\, /\, (1 - \alpha) \quad (2).$$

Because the analysis focuses on the long-term impact of concentration in complexity increase instead of having *t* represent continuous years, the analysis chose to use four-year windows. In this sense, in the equation for period t, the period $t - 1$ does not represent the previous year but he previous analytical period, that is, the previous four-year period.

To prevent distorting the analysis by including secondary effects in the coefficient that measures the long-term impact, a few controls have been added. Initially, to prevent the economies' natural convergence and divergence processes from impacting the measurement of coefficient b, the (previous period's) economic complexity index itself was added as a control. In addition, some control variables were selected that are usually employed in studies that seek to evaluate the determinants of countries' income and productivity, such as government spending, population, and economic openness degree. Government spending, gov, is generally used to measure its weight, which may have a positive or negative influence on growth. For openness degree, we chose exports as a share of GDP, exp. Inclusion of this variable is particularly relevant to this study because it reduces the bias generated by the use of export complexity instead of the productive structure as a measure of economic complexity. In addition, to avoid ignoring the effect of population growth on the change in economic complexity, we included the variable $gPOP$ to represent the population's geometric growth rate in the previous four years.

Table 1 shows the estimations' results. The first model has no controls; the second includes only the complexity index to control for the impact of convergence or divergence, and the third model includes all other control variables mentioned.

Table 1 Impact of concentration on the change in economic complexity

	(1) $dECI_t$	(2) $dECI_t$	(3) $dECI_t$
$dECI_{t-1}$	-0.00804	-0.0160	0.00957
	(0.0348)	(0.0375)	(0.0383)
$top\_pr_t\ ECI_{t-1}$	-0.00123**	-0.00376***	-0.00450***
	(0.000600)	(0.000778)	(0.000931)
exp_t		-0.102***	-0.107***
		(0.0168)	(0.0200)
			0.00117***
			(0.000439)
gov_t			-0.00241*
			(0.00137)
$gPOP_t$			0.0150
			(0.0154)
Constant	-0.00709	0.0812	0.102
	(0.0649)	(0.0714)	(0.0781)
Long-term impact (b)	-0.00122**	-0.00370***	-0,00454***
	(0.000600)	(0.000778)	(0.000931)
Observations	963	963	953
Number of code	122	122	122
Hansen test	3.528	7.637	8.607
Hansen p-value	0.966	0.664	0.570

Standard errors in parentheses; ***: p<0.01, **: p<0.05, *: p<0.1.

In every model tested, the long-term impact of concentrating imports in a single product on the change in economic complexity is negative at a significance of at least 5%. This means that, although benefits may ensue for income in the short run, production concentration is harmful to technological development in the long run. In the first model, which lacks controls, the coefficient that measures this long-term impact is a negative .00123. Analysis of the Hansen test, however, indicates that the model is underidentified. The p-value of the Hansen test is expected not to be very high (close to unity), as this indicates a lack of sufficient variables to ensure the exogeneity of the instruments. The second and third models, in their turn, show appropriate Hansen test values. The tests' p-values neither approach unity, which would indicate underidentification, nor lie below 5%, which would indicate overidentificaiton.

In the latter two models, the long-term impact is measured by the coefficient b, which derives from the coefficients connected with the short-term impact and the autoregressive term, again indicates a negative relationship between export concentration and increased economic complexity. This indicates, as noted, that the Dutch disease, which occurs when exports concentrate on a specific product, may reduce countries' economic complexity in the long run and, therefore, reduce their technological development. The value of the coefficients is apparently small (although statistically significant at 1%). However, because this is about an impact of the **level** of concentration on the **change** in complexity, the consequences can be quite significant. A coefficient of .00454, as in the case of the third model, indicates that, for every additional 1 p.p. of the main export, economic complexity is reduced by .00454 every four years. However, given that a country afflicted by the Dutch disease may have a single product accounting for 50% of its exports, as is often the case with oil exporters, the impact would be a reduction in complexity of .227 every four years. If such a country were to maintain this structure for 20 years, its complexity would decrease by 1.135, meaning that it could go from a situation such as Denmark's, with a complexity index of 1.284, to a level close to India's .102.

Despite the significant results that this analysis provides, we have not so far taken into consideration the complexity of the product that accounts for the largest share of the countries' exports. As discussed before, the Dutch disease does not stem exclusively from concentrating exports in a single product but from concentration in a low-complexity product. For this second stage in our analysis, we use heterogeneous regressions techniques (Agung 2014, Woodridge 2002) where the degree of exports concentration interacts with the product's complexity in such a manner that, instead of having the long-term impact b as a parameter, it works as function of the product's complexity. We begin by estimating the following model:

$$\mathrm{dECI}_{i,t} = o\ \mathrm{dECI}_{i,t-1} + \beta_1\ \mathrm{top\_pr}_{i,t} + \beta_2\ \mathrm{top\_pr}_{i,t} \cdot \mathrm{pci\_top}_{i,t} + y\ Z_{i,t} + a_i + \mu_{i,t} \quad (3),$$

where pci is the complexity index of the main export.

Unlike equation 1, equation 3 includes an interaction term in association with the coefficient $f3_2$.

This term, which is the product of the share of the main product in exports times its complexity index, allows analysis of the impact of concentration in low- or high-complexity products. In this case, the long-term impact coefficient, b, is given by equation 4 and, therefore, is a function of the product' complexity rather than a parameter as in equation 2.

$$b = \frac{f3_1 + f3_2 \mathrm{pci\_top}}{(1-o)} \quad (4)$$

As in the analysis that did not take product complexity into account, three models were estimated: one without controls; another controlling for the potential impact of natural convergence or divergence, and yet another that includes, in addition to the latter control, certain variables generally employed to prevent the relevant coefficient from absorbing secondary effects. Table 2 shows our results:

Table 2 Impact of concentration on the change in economic complexity considering the complexity of the main export product

	(1) $dECI_t$	(2) $dECI_t$	(3) $dECI_t$
$dECI_{t-1}$	-0.00684	-0.0252	0.000278
	(0.0311)	(0.0330)	(0.0328)
top_pr_t	0.00330**	0.00122	0.000898
	(0.00141)	(0.00140)	(0.00141)
$top\_pr_{i,t} \cdot pci\_top_{i,t}$	0.00157***	0.00198***	0.00225***
	(0.000486)	(0.000470)	(0.000490)
ECI_{t-1}		-0.118***	-0.126***
		(0.0157)	(0.0181)
exp_t			0.00128***
			(0.000396)
gov_t			-0.00197
			(0.00130)
$gPOP_t$			0.0178
			(0.0145)
Constant	-0.0443	0.0458	0.103*
	(0.0639)	(0.0690)	(0.0566)
Observations	963	963	953
Number of code	122	122	122
Hansen test	3.777	7.216	7.701
Hansen p-value	0.957	0.705	0.658

Standard errors in parentheses; ***: p<0.01, **: p<0.05, *: p<0.1.

In every model, the coefficient associated with the interaction term is statistically significant at 1% and shows the expected sign, indicating that a positive product complexity index has a positive impact on the change in complexity and that the lower this index and the greater the concentration in the product are, the greater the complexity reduction will be. However, since we are now analysing a function rather than a parameter, quantitative analysis of this impact becomes more concrete considering different product complexity indices. Table 3 shows some product complexity indices and the long-term impact of concentration in the respective products.

As the table describing the impact of each product shows, although concentration in a specific product may negatively impact countries' complexity growth, as in the case of oil, minerals, and soy beans (considering model 3, which is the most comprehensive), products exist that positively affect the change in complexity, such as medicaments, cars, personal computers, and microcircuits. Concentrating exports in oil, as do Nigeria, Colombia, Egypt, Oman, Yemen, Kuwait, and others, negatively impacts the country's complexity change by .00483 per percentage point. As previously analysed, if oil accounts for 50% of exports, the country's economic complexity will decrease by .242 every four years, meaning that complexity will drop by 1.208 over a period of 20 years. Similar results, albeit at a lesser scale, apply to iron ore, the main export product for Brazil and Australia, and soy beans, the main export for Uruguay and Paraguay. In contrast, concentration in more complex products has no negative effect on complexity change. To the contrary, the effect of concentration in microcircuits, which are the main exports for Malaysia, the Philippines, and Singapore, and in personal computers, which is the case of China, positively impacts complexity. Based on this analysis, one may infer that the Dutch disease, one of whose main symptoms is a high concentration of exports in low-complexity sectors, is an important factor in explaining the low technological development level of certain countries and, therefore, of their lower long-term economic growth.

Table 3 Impact of concentration on the change in economic complexity, examples of main export products

	ECI_{2013}	(1)	(2)	(3)	Countries
Liquid Petroleum Gases	-2.67383	-0.00089	-0.00397	-0.00512	Qatar
Crude Petroleum	-2.54636	-0.00069	-0.00373	-0.00483	Nigeria, Colombia, Egypt, Oman, Yemen, Kuwait
Iron Ore	-2.2224	-0.00019	-0.0031	-0.00410	Brazil, Australia
Soy Beans	-1.81141	0.000453	-0.00231	-0.00318	Uruguay, Paraguay
Petroleum Gases	-1.52749	0.000896	-0.00176	-0.00254	Bolivia, Netherlands
Copper	-0.43187	0.002604	0.000356	-0.00007	Chile, Bulgaria, Zambia
Medicaments	0.500071	0.004057	0.002156	0.002024	Ireland, Switzerland, Greece, Slovenia
Cars	0.587872	0.004194	0.002325	0.002221	Austria, Turkey, USA, Spain, Germany
Personal Computers	0.908917	0.004695	0.002945	0.002944	China
Electronic Microcircuits	1.4119	0.005479	0.003917	0.004076	Malaysia, Philippines, Singapore

5. Conclusion

To a certain extent, the results of the complexity and export concentration analysis shown here were expected; empirical investigation in the *Atlas of Economic Complexity* pointed in this direction. The complexity measures already use exports diversity as a criterion in their ECI calculations. The measures shown here are somewhat redundant. In contrast, the formal association between the excessive concentration of exports in products of low complexity and the general level of productive complexity of the various countries adds interesting analytical and empirical gains to the discussion of the Dutch disease. The intersection of the economic complexity literature with studies of the resource curse may provide new insights, such as the idea that productive specialisation in products such as oil or iron ore may not be fruitful from the angle of generating knowhow and innovation externalities; these are low economic complexity products. An interesting way to understand economic development is to think in terms of productive sophistication. Rich and developed countries are those capable of producing complex goods and selling them in world markets. The poor ones are those that can only produce and sell simple and rudimentary goods. This is why economic development can also be understood as a society's ability to know and control productive techniques, particularly in the more relevant world markets. This article attempts to contribute to this literature through economic complexity analysis applied to discussions of the Dutch disease.

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