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Raspberries vs Wheat: Economic Sophistication as a New Predictor of Income Volatility

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Abstract

In a series of recent papers, Hidalgo and Hausmann introduce a novel approach of measuring the nature of capabilities and knowledge accumulated in a country over time. With the development of Economic Complexity Index (ECI), the authors relate economic complexity to fundamental macroeconomic variables. In this paper, we study the ECI as a possible determinant of GDP growth volatility, hypothesizing over several channels through which the effect of a higher sophistication of production can be transmitted into a lower output volatility. Besides, we decompose the index into its two constituent parts – export basket diversification and the ubiquity of the products in this basket – as to test the effect of each component separately. In our panel regression with time- and country-fixed effects, we model a 5-year volatility in a sample of OECD countries over 1995-2015 as the functions of ECI and export diversity and ubiquity, combined with a set of control variables. In addition, we perform several robustness checks to affirm our main finding: the negative effect of ECI is mainly stemming from its ubiquity component, while the diversification part lacks any significance. We demonstrate that while the absolute effect of ubiquity on volatility is relatively high, the ubiquity itself is a slowly changing parameter, given its path dependence and countries' resilience to develop productive structures vertically. Our conclusions provide a new rationale for the industrial policy implementation, the subject that still involves polar opinions and contrasting views of scholars and policy makers.

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1. Introduction

Think of an example of two countries, each of them producing and exporting either raspberries or wheat. The former being a petit-bourgeoisie crop, and the latter a proletarian one (Scott, 1998). What does it imply for these two countries, apart from their comparative advantage in production of either crop? Intuitively, one can say that it is more difficult to produce one ton of raspberries rather than the same amount of wheat: the farmers cultivating raspberries need certain type of soil and use hand-picking in harvesting, putting up with the fragile nature of the crop that demands careful transportation and special storage conditions. As Scott (1998, p. 222) points out, "successful raspberry growing requires a substantial stock of local knowledge and experience", highlighting the idea that in fact, the types of goods produced in a country determine its economic and political structures: distinct and not perfectly substitutable human, physical and institutional capabilities accumulated within time at a country level and associated with specific production structures are the reason for that.

If one decides to decompose a product into its separate inputs, in addition to the raw materials used, they should also include highly product-specific knowledge and know-how, human capital and physical assets utilized, the type of a legal system, as well as institutions and infrastructure development, either contributing to or harming manufacturing process. These inputs are quite specific to every product, and once a country chooses to specialize in a good, it starts to acquire these inputs by developing a set of necessary capabilities and establishing a corresponding productive structure. The idea of productive structures, or in simple words, whether this is a raspberry or wheat based one-sector economy, as well as the importance of their structural transformation in explaining the economic development of a country, has been pioneered in the mid-20th century. For instance, Lewis (1955), Rostow (1959), and Kuznets (1966) view economic growth as a transformation of productive structures, resulting from resources moving from an agricultural to a manufacturing sector.

However, such a transformation is not an easy process: production capabilities, skills and competencies differ and are not perfect substitutes to each other, meaning that a set of accumulated capabilities in a wheat-based economy will hardly facilitate the development of a knowledge-intensive pharmaceutical industry. In this respect, countries will rather find themselves moving into manufacturing of the goods requiring already available capabilities, and leapfrogging in them is very unlikely.

Estimating the economic activity of a country and using measure of GDP for this purpose can only deliver a sense of its size, but tells little about the complexity of production structures. On the contrary, it seems to be unfeasible to distinguish between every product or service manufactured in the economy; even if we try, there is a risk to get a biased estimate: we need an expert's assessment of a product sophistication level, which is still an opinion of a particular individual.

Recently, two prominent scholars – Hidalgo and Hausmann (2009) put forward a full-fledged theory of economic complexity, developing a novel approach for ranking each product based on the variety of capabilities embedded into them. The authors view economic development as the ability to produce and export more products as well as the products of a higher degree of sophistication, thus relating accumulated capabilities to the overall economic development.

As different products require different skills, we can indirectly infer the number of locally available capabilities by looking at what countries produce and export in terms of diversification (how many various products) and ubiquity (how complex the products are). As a result, a country's export matrix reveals a set of accumulated knowledge and capabilities accrued from the nature of production activities. Even though both raspberry and wheat have the agricultural sector code, if we disaggregate these products into the type of experience and a bunch of skills required for their cultivation, those will clearly differ.

The intuitive analogy here is a game of scrabble. Let a letter stand for a capability available in a country, while a word will indicate a product a country can produce. The more letters a country has, the more words it can create (diversification), as well as the length of the words increases (ubiquity). It is also possible to align this analogy with the methodological approach used in the complexity theory: "[the] measure of economic complexity corresponds to estimating what fraction of the alphabet a player possesses, knowing only how many words he or she can make, and how many other players can also make those same words" (Hausmann et al., 2014, p. 20). In this case, the players are the countries – a primary focus of the theory.

Consequently, by employing a novel technique for estimating a valuable characteristic of a country, a new measure is derived. The development of Economic Complexity Index (ECI), capturing the nature of productive capabilities accumulated in a country, stimulates further research into its relation with fundamental macroeconomic variables. Due to the novelty of complexity theory, it has not been widely applied yet and was mainly tested by its originators with regard to economic growth and income inequality, confirming the explanatory power of ECI (Hidalgo & Hausmann, 2009; Hartmann et al., 2017).

In our paper, we extend the view on the effects of economic complexity in relation to the key macroeconomic variables, namely, by measuring its impact on GDP growth volatility in a sample of developed countries. The business cycle volatility is closely linked to the stability of GDP growth, while the primary objective of counter-cyclical policies is in diminishing its persistent negative effect onto economic productivity.

We set our study focus on the further research into the determinants of GDP growth volatility. For instance, the export basket diversification and its interaction with the country's openness are intensely studied in relation to income volatility (Jansen, 2004; Haddad et al., 2011). In our research, we contribute to the previous studies by observing empirically the effect of complexity on income growth volatility: we hypothesize that since the complexity index incorporates not only the diversity of exporting products, but also accounts for the nature of them, it might find its statistical significance in our analysis of income volatility.

Specifically, we argue that the countries which produce less ubiquitous products experience less output volatility. The idea behind the argument is that more complex products require more inputs, have more human capital embedded into their production, and enjoy more demand from rich countries. As a result, the level of economic complexity smooths the effect of negative exogenous shocks and makes a country less vulnerable to any market fluctuations.

Thus, our research question is: "Does the Economic Complexity Index serve as a statistically significant predictor of GDP growth volatility in a sample of OECD countries?" The choice of the study sample is primarily driven by the better quality of data available for OECD countries, and hence, a lower probability of measurement errors. In addition to this, given that income volatility is region specific (Rodrik, 1997), the choice of developed countries allows us to cut considerably the number of control variables, in some of the cases having no specific proxies.

We provide the empirical evidence for OECD countries over 1995-2015, explaining income volatility by ECI and the exports diversity and ubiquity in the presence of multiple control variables. In our model, we distinguish between the diversity and ubiquity variables as to observe the effects coming from each of the ECI components.

The work is structured as follows: the next section reviews the existing research on theoretical growth models, the ambiguity of volatility effect on economic growth, the income volatility determinants as well as presents the theory of economic complexity in more details. Section 3 describes the methodology of the research, and in Section 4, we present the empirical results and robustness checks in conjunction with discussion paragraphs. Section 5 concludes.

2. Literature Review

Volatility and Growth: Theory and Empirical Findings Heterogeneity

Economic growth has been always on the agenda of academics and policy makers. In a pursuit of growth stability, high volatility has been commonly associated with amplified economic risks and vulnerability. Apart of this, some researches relate high income volatility to persistent unfavorable effects on a long-run growth trend it has (Ramey & Ramey, 1995; Aizenman & Pinto, 2005). Particularly, this is of relevance for the OECD members, where a statistically significant negative relationship between long-term growth and volatility did not find any contradiction among scholars (Ramey & Ramey, 1995; Rodrik, 1997).

One of the most recent academic studies exploring the nature of the relationship between economic growth and business cycle volatility is the work of Bakas, Chortareas, and Magkonis (2017). In their paper, the authors employ a methodological framework which is per se quite a rare, yet very valuable finding in economic literature. This is the first attempt of a meta-analysis used in the research on economic growth and volatility relationship, summarized over a course of the last three decades.

Meta-analysis represents a systematic and in-depth quantitative review of a multitude of scientific studies associated with a specific phenomenon, theory, or effect. As Bakas et al. (2017) portray, the interest towards the effect of business cycle volatility on national income growth is twofold: not only the existing empirical evidence is conflicting in its final estimates, but also theoretical approaches lack a clear consensus. Integrating a pool of 84 empirical studies exploring the direction of volatility effect on economic growth, the authors demonstrate that 41% of them specify a statistically significant negative effect, 17% – statistically significant positive effect, while the remaining 42% indicate no any significant relation at all. Drawing on these rather contradicting estimates, we would like to shed some light on the nature of such a heterogeneous relationship. This intent traces us back to the origins of a business cycle theory, its development and incorporation into the economic growth models.

Several decades ago, business-cycle theories and economic development theories were separated. The studies distinguished between the cyclical and non-cyclical components of domestic income, interpreting any changes in the economy as irregular comovements around an independent long-term growth trend. In some cases, those fluctuations were characterized by their non-cyclicality, thus generating little support for their in-depth analysis. The underlying assumption behind this view accrued from the standard dichotomy in the macroeconomics: for a long time, it was considered that national income growth as a widespread measure of macroeconomic activity was unrelated to the business-cycle volatility. Thus, as Martin and Rogers state (2000), “business cycle theorists have considered long-term growth as an exogenous trend and growth theorists have typically worked with models where short-term shocks have no impact on the long-run growth rate of the economy” (p. 359-360). In 1987, Robert Lucas, studying the models of business cycles, affirmed this idea: he suggested that a primary effort should be put into the research on the income growth determinants, rather than on the theories trying to understand economic fluctuations. He explained that the latter, in turn, yields minor possible returns comparing to the former.

This dichotomy perspective changed with the development of a real business cycle theory, when the theory of cyclical movements was incorporated into the analysis of economic fluctuations by several scholars (Nelson & Plosser, 1982; Kydland & Prescott, 1982; King, Plosser, & Rebelo, 1988; Mankiw, 1989). The real business cycle theorists proposed to alter the existing perspective, postulating that business cycle movements are indeed an integral part of a country’s output growth and there exists a decent economic reasoning for that (Kydland & Prescott, 1982; Long & Plosser, 1987).

There were several events that brought volatility to the fore.

At first, one of the prominent papers in the field, written by Garey Ramey and Valerie Ramey (1995), presented the empirical evidence on the existence of a strong negative link between volatility and growth. As the authors argue, this effect primarily stems from the volatility of technological innovations that reflect the degree of uncertainty in the economy. Assuming that a profit-maximizing firm has advance commitments to its technologies, it tends to end up with an optimal production level as to minimize the overall cost structure of a company. However, to the extent that the expected production output of a firm impacts its current technology choice, anticipated economic fluctuations in the form of productivity disruptions lead such a firm to reduce its future production level and are reflected into its technologies changes. Hence, as every company chooses to produce less, it has an evident negative effect on the aggregate domestic output (Ramey & Ramey, 1991).

The authors develop the analysis using two different samples – a panel of 92 countries and a separate subset of OECD member countries. In both samples, the negative relation stays robust to a set of control variables captured in either country- or time-fixed effects. Interestingly to note for our research: the volatility was rated second in terms of its impact magnitude in the subset of *OECD countries*, listed right after the initial level of GDP.

The contribution of Ramey and Ramey (1995) spurred the academic interest once the explanatory power of income volatility to GDP growth was proved to be empirically robust. The number of academic publications on the topic considerably increased at that time while the extant literature on the interrelation between income growth and volatility vastly builds on the grounds of Ramey and Ramey's (1995) empirical study (Bakas et al., 2017).

The point that is worth additional attention is the type of a growth model itself: in fact, this is what prescribes the sign in the volatility-growth relation. According to several scholars (Aghion & Saint-Paul, 1998; Martin & Rogers, 2000), the theory-based explanations of the effect of income volatility on economic growth are dependent on how we treat the very mechanism of macroeconomic growth origination. In other words, the choice of the theoretical model of economic growth development matters.

The positive correlation of growth and volatility was supported by several economists within various time periods, with the first theoretical argument coming from the Schumpeter's (1939, 1942) idea of "creative destruction". As the author explains, the economic development occurs through the processes of economic expansions and recessions, emphasizing importance of production innovation in this process. It is exactly during the turmoil periods when the most crucial part of the development takes place: an old technological knowledge base is replaced by newer, giving a rise to productivity and a stimulus to economic growth. The positive relation finds its alternative theoretical justifications and support in the papers of Hall (1991) and Caballero and Hammour (1994), as well as Black (1987), who proposes the analogy of a well-known risk and return trade-off in finance, however, with regard to a growth-volatility relationship.

On the contrary, the second strand of academic studies incorporates the endogenous models of economics growth, highlighting the existence of a negative correlation between growth and volatility. To cite Aizenman and Pinto (2005), "the inclusion of volatility in the growth literature can be regarded as a continuation of the trend that began in the mid-

1980s with endogenous growth theory" (p. 2), thus, providing additional reasoning for the gained prominence of income volatility in academic research.

These types of models, in contrast to exogenous or traditional neoclassical approaches, link the productivity enhancement to the improvements in internal country's processes, with a particular focus on a human capital component. Pioneered by Arrow (1962), his idea of a "learning by doing" mechanism as an integral part of human capital formation and productivity enhancements has been embedded into a plethora of academic works. The dynamics of learning by doing imply that the accumulation of knowledge takes place through experience and repetition: over time, the lower quality goods find replacement by higher quality ones and the spillover effects are in place due to a bounded nature of a continuous productivity enhancement (Stokey, 1988). In this case, the nature of a negative growth-volatility relationship is explained by the detrimental impact that short-term negative shocks and disturbances can have on average productivity, and hence, undermining the sustainability of economic growth.

Martin and Rogers (2000), studying the effect of volatility for the samples of both OECD countries and 90 European regions, find a strong negative link in a volatility-growth relation. The authors hypothesize that the mechanism of learning by doing per se can account for the observed negative relationship and test it empirically. They discover that the observed relation stays robust to the inclusion of an investment share in GDP as a control variable in their econometric model. This evidence implies that a changing level of investments, affected by short-term business cycle fluctuations, does not provide a natural explanation for the negative link between volatility and growth. Thus, "the link between fluctuations and growth then would rely neither on uncertainty nor on an investment channel but on a labour channel" (p. 361). In addition, they outline non-significance of the results obtained for developing countries, which is in line with Young's (1993) explanation of a similar result: in an endogenous growth model, learning by doing affects the growth only at quite high levels of development.

Coming back to the abovementioned meta-analysis of Bakas et al. (2017), we would like to point out that the type of volatility measures (standard deviation or GARCH-based estimates) and certain research design aspects (e.g., the choice of control variables) were listed among the main sources of observed heterogeneity in empirical studies on a volatility – growth relationship. However, the authors decide to go further: they also classify various control variables in accordance with their explanatory power by employing own methodological approach. Interestingly, human capital measure had the highest explanatory power among all other characteristics aggregated by the authors, such as government size, inflation rate, investment level, and others. To recall, human capital is at the core of endogenous growth models, and in particular, a "learning by doing" mechanism. Moreover, as Bakas et al. (2017) notice, the inclusion of a proxy for human capital leads to more negative estimates of volatility coefficients. The same evidence was proven by Aghion and Banerjee (2005), after accounting for a secondary school enrolment variable.

What we have shown so far is that there is an ambiguous, yet in most of the cases present effect of business cycle volatility on income growth. While the conclusions derived by Ramey and Ramey (1995) established the initial surge of interest towards the nature of volatility – growth relation, the absence of any consensus on this topic requires additional attention. One of the reasons is that a better understanding of its underpinnings plays a crucial role in the choice and design of counter cyclical policies, developed as to minimize the detrimental effects of external fluctuations and shocks in the economy. As we discussed before, short-term negative shocks might have a persistent impact on the average productivity in the economy, or in other words, good times do not always offset bad times. The other part of the story is about addressing the existing contradicting views by studying the output volatility itself. Understanding what affects business cycle volatility and its variation in different countries provides another perspective on the relation between income growth and volatility: not only well-tailored counter cyclical policies, but also the mechanisms for decreasing volatility magnitude play a crucial role. As Aizenman and Pinto (2005) suggest, "the so-called deep determinants" of output volatility – trade openness, geography, political institutions and financial market development might either magnify or alleviate the effect of volatility on GDP growth (p. 2). With this in mind, we take a closer look at the determinants of output volatility.

Output Volatility Determinants

The vast majority of academic papers specify several major determinants of output volatility, among which are the terms of trade volatility, the degree of openness to trade, economic concentration (or, the opposite measure – economic diversification), population as a proxy for the size of economy, the degree of institutions development, financial system development, etc. (Malik & Temple, 2009; Jansen, 2004; Easterly, Islam, & Stiglitz, 2000; Acemoglu, 2003). However, while the positive effect of the terms of trade volatility on the output volatility did not encounter any contradictions among the scholars, the discussion emphasizing the role of openness and export concentration has involved contrasting opinions (Easterly & Kraay, 2000; Jansen, 2004).

As Giovanni and Levchenko (2009) argue, while a plethora of studies identify trade openness as one of the determinants of output volatility, exhaustive academic research on the possible channels between these two variables is missing. The authors develop three main hypotheses on how a greater degree of trade openness can be transmitted into a growing volatility. At first, they argue that with a higher trade openness, the volatility of each individual sector increases as they become more vulnerable to external shocks. Secondly, they specify that not only the openness of individual sectors, but also the comovements across sectors matter: it can be the case that once the volatility of an individual sector changes, it also becomes less exposed to domestic cycle fluctuations. Thirdly, a higher degree of openness might lead to a higher concentration of a country's economic sectors. For instance, a country can have a shift to a more export oriented and less diversified production range, which is hypothesized to serve as an additional channel for a higher volatility.

Investigating the growth and income volatility in small states, Easterly and Kraay (2000) affirm that as a result of a greater trade openness, the income growth volatility as well as the terms of trade volatility in small states are considerably higher comparing to their larger counterparts. Relying on the imports to meet its domestic demand, smaller economies choose to be more open. However, their export-oriented sectors stay highly concentrated, and in most of the cases, confined by a country's economy size. In this respect, the size only aggravates the problem: the countries experience less options for diversification, being limited by returns to scale or indivisibility of production factors. While trade openness plays a significant role in volatility analysis, Jansen (2004) argues that it is hardly possible that this characteristic alone can explain the output volatility: the sector concentration, for some reason disregarded by Giovanni and Levchenko (2009), is also a big part of the story.

In his analysis, Jansen (2004) compares small states (defined by the population size) with the least developed countries (LDCs) in terms of their income volatility and trade openness. Despite the fact that LDCs are evidently characterized by a lower degree of trade, the average output volatility in this group of countries appears to be comparable with the same parameter in small states. The result obtained by Easterly and Kraay (2000) demonstrates a necessity to examine the other possible determinants of GDP volatility further.

Based on his finding, Jansen (2004) suggests that export concentration should be taken into account. Looking from the perspective of a small county, it is not desirable to sacrifice its openness for the reduction in domestic income fluctuations, which will entail a drop in the overall economic welfare. Instead, a country can benefit from the diversification opportunities. As the author observes, high export concentration can directly affect terms of trade volatility, thus making a country's economic performance even more sensitive to external fluctuations. Moreover, as microstates commonly specialize in commodities, which are prone to higher price changes compared to other product types, this amplifies the negative effect of sectoral concentration on output volatility.

In 2011, Haddad et al. in their research on volatility, export, and diversification, demonstrate that the effect of trade openness on volatility is conditioned upon the diversification degree of a country's export basket: openness makes the poorly diversified countries more vulnerable to global exogenous shocks while highly diversified countries are considerably shielded from the same external fluctuations. Apart from finding the precise numerical value for a threshold at which the effect from openness changes its sign from negative to a positive one, the authors also argue that as the first-order policy for a country seeking to reduce its income volatility should become the one with its focus on export diversification and withdrawal of protectionism instruments. An interesting addition to this is the observation that the countries which were characterized by a high degree of export concentration, for instance, China, Mexico and Jordan, but deliberately pursued a path of diversification, achieved recognizable results within a period of 10-15 years.

As Malik and Temple (2009) suggest, one of the perceptions of income volatility is that "it emerges primarily in the form of economic crisis" (p. 164). There is an empirical proof that the output volatility experiences an immense increase during the periods of economic turmoil. However, as the authors contend, there are inherent characteristics that might explain the high value of this parameter for developing countries, which makes it not solely confined to the periods of crisis. For instance, standard deviation of annual GDP growth rates in developing countries exceeded threefold the same value in OECD countries from 1960 to 1999 (Malik & Temple, 2009). Besides, as Giovanni and

Levchenko (2009) point out, an identical increase in trade openness in both developed and developing countries results into a different incremental change in output growth volatility, being five times greater in an average developing country.

Koren and Tenreyro (2007) investigate the relation between output volatility and economic development while being interested in the reasons that lie behind the considerably higher GDP growth volatility in poor countries comparing to rich countries. Among the reasons the authors identify are the following ones: firstly, this is the intrinsic nature of specialization of poor countries in more volatile economic sectors (for instance, in agricultural commodities); secondly, it can be the case that small countries themselves are more prone to severe detrimental consequences and shocks from macroeconomic fluctuations; and thirdly, the magnitude of frequent aggregated shocks can differ across various sectors, with the highest identified in the sectors a country has the highest specialization in. After the performance of volatility decomposition and assessment of the contribution every component adds to the total value of income volatility, the authors find support for two hypotheses. In fact, they observe that as a country develops, the production structure in which it specializes moves from a highly volatile sector to a less volatile sector. Moreover, the poor countries indeed experience higher in magnitude shocks from economic fluctuations, which, however, falls with the increased degree in a country's economic development. Hence, economic development plays a significant role in the income volatility analysis, and as stated by Jansen (2004), should be observed separately as to be able to disentangle its effect from a country's economic size.

Acemoglu et al. (2003) study the impact of institutions and their development on income growth and volatility. As it is outlined in the study, the empirical evidence suggests that the countries which were a subject to distortionary macroeconomic policies during the postwar period experienced higher rates of output volatility as well as lower GDP growth. Thus, this posited a question of whether the macroeconomic policies of high inflation and budget deficits were the primary source of output fluctuations. Acemoglu et al. (2003), after controlling for both macroeconomic policies and institutions, conclude that the institutional differences were the root cause of income volatility, with the distortionary macroeconomic policy and the corresponding macroeconomic variables serving as channels rather than the initial determinants.

The significant role of institutions in relation to income volatility is also observed by Malik and Temple (2009). The authors perform a profound analysis in relation to another structural determinant of income volatility – geography, while exploring "the volatility effects of market access, climate variability, the geographic predisposition to trade, and various measures of institutional quality" (Malik & Temple, 2009, p. 163). Providing a wide discussion on the existence of various barriers and transportation costs for the countries in different geographical locations, their main finding constitutes the fact that the countries situated in the most remote areas and regions are more likely to have export concentration and can suffer from a higher output growth volatility.

Another structural determinant of income growth volatility studied in the literature is the development of a financial system. Easterly et al. (2000) use a multitude of finance-related variables in their analysis of output volatility, for instance, financial depth, defined as credit to private sector as a percentage share of GDP, volatilities in money supply aggregates, stock market and private/public bond markets value traded as a percentage of GDP. As the authors discuss, there are two types of effects in association with output volatility – stabilizing and destabilizing ones, that primarily depend on the size of a financial system itself. The reasoning behind it is that a developed financial sector smooths consumption and production, while at the same time, the additional risks are born by a higher degree of financial leverage. Besides, the authors find a non-linear relation between financial depth and volatility: they argue that a larger financial sector magnifies the external shocks through the capital inflows and outflows, but the amplitude of this effect is not proportional to the size of a financial sector. The main finding of the paper, however, relates to a parameter of a deeper financial sector development and its significance with regard to growth volatility.

To sum up, we can identify various factors which are channelled into the analysis of income volatility: trade-related mechanisms, individual characteristics of the countries, such as their geographic locations, the current stage of economic development and the economy's size, as well as institutional and financial system determinants. In this paper, we are going to study a possible determinant of income growth volatility that is not easily classified into trade-related mechanisms or a country's idiosyncratic factors, but rather has the features of both – a country's economic complexity and the corresponding quantitative measure of it – the Economic Complexity Index (ECI). By composition, economic complexity is closely related to the export diversification measure discussed earlier, however, has a considerably different idea underneath. In the next sections, with the introduction of the economic complexity theory and elaboration on the Economic

Complexity Index composition, we are going to argue that it is not diversification as such, but primarily, whether this is a diversification into raspberries or wheat, is what should be considered at the first place while studying income growth volatility.

The Economic Complexity Theory

In 2009, Hidalgo and Hausmann introduced a new theory, which attempts to describe the productive knowledge available in a country. They argue that the things manufactured are not merely confined to accessible physical materials used in their production, but also require the production knowledge to be present in a country. It is not enough to have metal to build a car, one also needs to have a profound knowledge in electronics, engineering and metallurgy, to name a few.

While each individual's bunch of skills and knowledge is limited to some degree, the markets allow us to combine them together in organizations and factories, and later reproduce by creating sophisticated products. As a result, it is not the individual brilliance that matters, but the diversity of knowledge and the possibilities to combine it. Herein, the individual chunks of knowledge are called capabilities.

The number of different capabilities in a country determines its complexity and besides, can be derived from the composition of its production. Only the countries which possess all the necessary capabilities can combine them to make a complex product.

But how to estimate *numerically* available capabilities? Hidalgo and Hausmann propose to look at the export data as it is most closely resembling the production of a country, and to focus on the two key factors: diversity and ubiquity.

Diversity is the number of different products that a country exports with a comparative advantage. Countries with a lot of productive knowledge usually can be competitive in a variety of industries as their capabilities are disseminated among different areas. As a result, they produce and export a very wide range of goods. But looking only at the diversification might lead us to the problem that we "cannot distinguish between countries exporting 10% bananas and 90% mangos, 90% bananas 10% mangos, or 10% motorcycles and 90% aircraft engines" (Hidalgo & Hausmann, 2011, p. 7).

That is why the theory goes deep into the products sophistication by measuring their ubiquity. To calculate the ubiquity of a product, one estimates the total number of countries that export it. Few countries are able to produce semiconductors or airplanes, while wheat or oil is found in many countries across the globe. Thus, by looking at the number of other countries exporting a good as well as the overall composition of their export baskets, we can arrive at the average ubiquity of a country's products.

The Economic Complexity Index combines the information both about the number and the type of products, while its detailed mathematical calculation can be found in the methodology section.

Applying the complexity index to macroeconomic links, Hidalgo and Hausmann present the evidence on the relation of economic complexity to the level of domestic income, as well as demonstrate that the deviations from the econometric model are predictive of future growth, which broadens the application of ECI for further academic research. As a consequence, Hidalgo and Hausmann (2009) conclude that the convergence towards a specific country's income is primarily determined by the degree of its production complexity.

In the meantime, the effect of complexity was observed in relation to income inequality. In this case, economic complexity has a significant negative effect on the level of income inequality, demonstrating that the countries with a complex structure of their exports ultimately have less disparity in their income structure (Hartmann et al., 2017). Quite recently, the same network analysis approach was employed on a sub-national level among 50 Spanish provinces (Balsalobre, Verduras, & Lanchas, 2017) as well as on the cities level in the USA (Balland & Rigby, 2017), with the significant results derived in both studies.

While a novel index of economic complexity has been primarily used in academic studies in order to observe its impact on wealth, GDP, and income inequality (Hidalgo, 2009; Hidalgo, 2017), there is no evidence demonstrating its link with output volatility. Given a more holistic nature of economic complexity index in comparison with other indices approximating product or geographical diversification (e.g., Herfindahl-Hirschmann index), it is of a high interest to us to study which part of GDP volatility can be explained by the level of a country's economic complexity.

The Theoretical Channels behind Complexity and Volatility

Many researchers have noted that poor countries experience higher macroeconomic volatility (Lucas, 1988; Koren & Teneyro, 2007). A number of explanations for that phenomenon focuses on the complexity of countries' products, with different theories being proposed to explain how exactly complexity channels into output volatility.

In the following section, we explore possible mechanisms behind a negative association between a country's complexity and economic growth volatility. We draw on the existing literature in the area of complexity and economic growth studies and provide the evidence from both theoretical and empirical research.

First, there is a wide body of literature relating the low volatility of the complex products to their resilience to external shocks. Krishna and Levchenko (2013) model sectoral volatility as the function of its complexity (measured by the number of intermediate inputs), and find that more complex industries are less volatile due to their increased resilience to exogenous shocks. When there is a variety of inputs used in a production process of a specific good, a single input-specific shock is unable to significantly alter the output.

Maggioni, Lo Turco, and Gallegati (2016) yet argue, echoing Hidalgo and Hausmann's theory, that "considering only the number of inputs required in production partially neglects the fundamental role of knowledge in complex productions" (p. 102). They claim that a production comprised of many inputs is also characterized by skilled labour and more sophisticated production technology, so, considering only the number of inputs is indeed misleading. They use both the quantity of imbedded inputs and human capital intensity of products as the variables for explaining firm-level output fluctuations. The findings show that the effect of complexity on volatility largely represents the effect of a larger share of human capital contained in complex products – thus, validating HH's capabilities theory on a micro-level.

Another branch of research emphasizes a lower elasticity of substitution as the main reason behind low volatility of complex products. Kraay and Ventura (2007), for example, argue that industries with skilled workers and considerable technological knowledge face less elastic demand, thus, experiencing a smoothing effect from the business cycle movements. Moreover, the demand for more complicated products largely comes from rich countries – a notion supported by Hallak (2006), who also observes that rich countries have a tendency to import more from countries specializing in high quality products. With this, it becomes possible to predict that while rich countries might appear less sensitive to negative economic environment conditions, their consumption of complex goods, and hence, their imports, will not see an abrupt fall during various business cycle phases. Consequently, the more complex product is, the less market volatility it experiences, benefited by its sophisticated nature and wealthy consumers.

In sum, we see that the theory provides us with several possible hypotheses on how the products complexity can affect the volatility of growth. While the theoretical discussion gives us an overall perception of the possible economic mechanisms lying behind the volatility – growth relation, in the next section we introduce our methodology framework as to familiarize a reader with our quantitative econometric model, underpinning further results analysis.

3. Methodology

Data

In our paper, we use two major types of data: (a) international trade flows data, used for calculations of diversification, ubiquity and the Economic Complexity Index (ECI); and (b) macroeconomic data used for control variables.

We use the international trade data provided by Hidalgo and Hausmann at the Observatory of Economic Complexity website (2018). They take raw data from UN Comtrade database (an exporter, an importer, a product and a year) and adjust it using the Bustos – Yuldrim Method to account for inconsistent reporting. We use the data for a 20-year period from 1995 to 2015, classified by Standard International Trade Classification (SITC).

Table 1. Description of the dataset

Variable name	Definition	Source
VOL	Standard deviation of annual GDP growth rate	World Bank
GPC	GDP per capita in real terms	World Bank
TOT	Terms of trade volatility	OECD
OPEN	Total trade as a share of GDP	World Bank
SPEN	General government spending as a share of GDP	World Bank
CRED	Credit to the private sector as a share of GDP	Eurostat, BIS
VA	Voice and accountability	World Bank
PV	Political stability and violence	World Bank
GE	Government effectiveness	World Bank
RQ	Regulatory quality	World Bank
RL	Rule of law	World Bank
CC	Corruption control	World Bank
DIV	Diversification	Own calculations
UBI	Ubiquity	Own calculations
ECI	Economic Complexity Index	Atlas of Ec. Complexity

As for the control variables, we use economic and institutional data provided by international organizations. The list of the variables chosen as controls is based on the previous research in the area of income volatility and its determinants (Table 1). We choose 35 current members of OECD for our sample due to a better quality of the data available for these countries.

Revealed Comparative Advantage

In assessing the complexity of a country's economy, we use the export data. However, countries export a wide range of products, and some – in very small quantities. That is why we must distinguish ancillary exports from the exports that are truly representative of a country's capabilities. Thus, we use the concept of Revealed Comparative Advantage (RCA), similarly to Hidalgo and Hausmann (2009) and other research.

Revealed Comparative Advantage measures if a country's share in export of a good is larger than the share of the same good in the world market. Mathematically, it is represented as

$$RCA_{cp} = S_{cp}/T_p,$$

where S_{cp} is a country c share of exports of a product p in export basket, while T_p is a share of a product p trade in the world market.

By definition, the country has Revealed Comparative Advantage in a product when RCA≥1.

Method of Reflections

To calculate diversification, ubiquity, and eventually ECI, we employ the Method of Reflections developed by Hidalgo and Hausmann (2009). Although the method is useful for analyzing both countries and products, in our study we focus on country-related metrics.

First, the diversification of a country is calculated as the number of products exported by a country with RCA and the ubiquity of a product as the number of countries exporting it with RCA. The country which exports many products with RCA is more diversified, while the product which is exported with RCA by fewer countries is less ubiquitous.

In a scrabble analogy, diversification is how many words a country can make, while ubiquity is how many countries can make a word. The more diverse countries make more words, and more long words are made by few countries.

First, we define a country – product matrix M_{cp}, where the entry is equal to one if $RCA_{cp} \geq 1$, and zero otherwise.

Then, diversification and ubiquity are calculated as follows:

$$k_{c,o} = \sum_p M_{cp} \ (Diversification\ of\ a\ country),$$

$$k_{p,o} = \sum_c M_{cp} \ (Ubiquity\ of\ a\ product),$$

where c is a country, p – a product.

Based on the first two measures, the Method of Reflections goes on to generate the higher-order elements iteratively, adding the information from the previous reflections. The formulas for the N-th reflection are given by:

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_p M_{cp} k_{p,N-1},$$

$$k_{p,N} = \frac{1}{k_{p,0}} \sum_c M_{cp} k_{c,N-1}.$$

The interpretation of values generated in the first three iterations is provided in Table 2.

Table 2. Interpretation of the Method of Reflections' first three iterations

Definition	Description
$k_{c,0}$	Diversification – number of products exported by country c
$k_{p,0}$	Ubiquity – number of countries exporting product p
$k_{c,1}$	Average ubiquity of products exported by country c
$k_{p,1}$	Average diversification of countries exporting product p
$k_{c,2}$	Average diversification of countries with an export basket similar to country c
$k_{p,2}$	Average ubiquity of the products exported by countries that export product p

Source: Supplementary material for "The Building Blocks of Economic Complexity", Hidalgo & Hausmann (2009, p. 8).

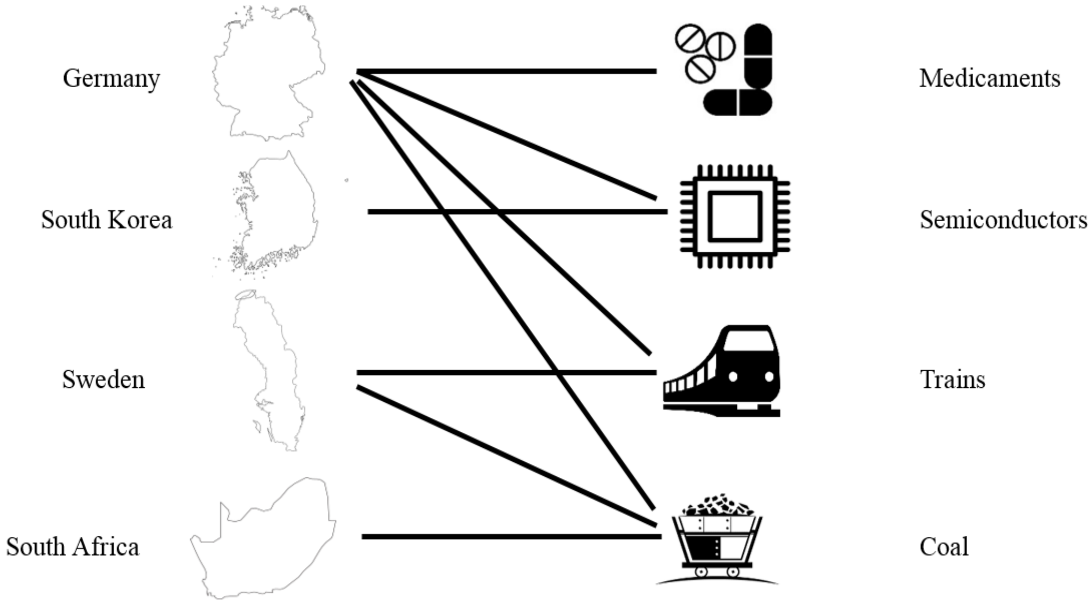
It becomes more difficult to intuitively interpret the results of the higher-order iterations, but generally, any country or product can be characterized by vectors of calculated elements:

$$\overrightarrow{k_c} = (k_{c,0}, k_{c,1}, k_{c,2}, \dots, k_{c,N})$$

$$\overrightarrow{k_p} = (k_{p,0}, k_{p,1}, k_{p,2}, \dots, k_{p,N})$$

The only general interpretation that could be provided here is that of Hidalgo and Hausmann (2009, p. 10571): "For countries, even variables $(k_{c,0}, k_{c,2}, k_{c,4}, \ldots)$ are generalized measures of diversification, whereas odd variables $(k_{c,1}, k_{c,3}, k_{c,5}, \ldots)$ are generalized measures of the ubiquity of their exports. For products, even variables are related to their ubiquity and the ubiquity of other related products, whereas odd variables are related to the diversification of countries exporting those products."

Figure 1. A map of a simple network used for demonstration of Method of Reflections



Source: Adapted from Hidalgo and Hausmann (2009, p. 11).

The result of the Method of Reflections is the two indices that measure the product ubiquity of a country, $k_{c,N}$, and its product sophistication, $k_{p,N}$.

For a more intuitive understanding of the method, consider a simple example with four countries trading four products. Germany has a revealed competitive advantage in all four products, South Korea – in semiconductors only, Sweden – in trains and coal, while South Africa – in coal only (Figure 2).

The first iteration calculations provide us with the figures for the diversification of the countries and ubiquity of their products.

$$k_{GER,0} = 4 \qquad k_{MED,0} = 1$$

$$k_{KOR,0} = 1 \qquad k_{SEM,0} = 2$$

$$k_{SWE,0} = 2 \qquad k_{TRA,0} = 2$$

$$k_{ZAF,0} = 1 \qquad k_{COA,0} = 3$$

Germany comes up as the most diversified country, while medicaments appear to be the least ubiquitous product.

Further, we compute the first iteration, which shows the average ubiquity of a country's products and the average diversification of a product's exporters.

$$k_{GER,1} = \left(\frac{1}{4}\right)(1 + 2 + 2 + 3) = 2 \qquad k_{MED,1} = \left(\frac{1}{1}\right)(4) = 4$$

$$k_{KOR,1} = \left(\frac{1}{1}\right)(2) = 2 \qquad k_{SEM,1} = \left(\frac{1}{2}\right)(4 + 1) = 2.5$$

$$k_{SWE,1} = \left(\frac{1}{2}\right)(2 + 3) = 2.5 \qquad k_{TRA,1} = \left(\frac{1}{2}\right)(4 + 2) = 3$$

$$k_{ZAF,1} = \left(\frac{1}{1}\right)(3) = 3 \qquad k_{COA,1} = \left(\frac{1}{3}\right)(4 + 2 + 1) = 2.33$$

Here, we immediately see how the method corrects itself taking the information from the previous reflections. Although Germany exports 4 products, while Korea – only one, the method identified that the countries' average ubiquity is the same.

The second reflection uses the same numbers in the first parentheses, but now the estimates from the first reflection are used as inputs for the second iteration.

$$k_{GER,2} = \left(\frac{1}{4}\right)(4 + 2.5 + 3 + 2.33) = 2.83 \qquad k_{MED,2} = \left(\frac{1}{1}\right)(2) = 2$$

$$k_{KOR,2} = \left(\frac{1}{1}\right)(2.5) = 2.5 \qquad k_{SEM,2} = \left(\frac{1}{2}\right)(2 + 2) = 2$$

$$k_{SWE,2} = \left(\frac{1}{2}\right)(3 + 2.33) = 2.66 \qquad k_{TRA,2} = \left(\frac{1}{2}\right)(2 + 2.5) = 2.25$$

$$k_{ZAF,2} = \left(\frac{1}{1}\right)(2.33) = 2.33 \qquad k_{COA,2} = \left(\frac{1}{3}\right)(2 + 2.5 + 3) = 2.5$$

As the even reflections are generalized measures of diversification, Germany again comes up at the top in terms of its diversity, while Korea now obtains a higher value of ubiquity than South Africa, even though they both export only one product.

The example and calculations above show how the Method of Reflections ranks the diversity and ubiquity of countries based on the export data only. The null-iteration, calculating the number of products being exported, correctly identifies Germany as the most diversified country, while two countries in our example – Korea and South Africa – export only one product each. The only difference is that South Africa exports coal, which is produced by all countries, while Korea exports semiconductors (together with the most diversified country – Germany).

As we continue with calculating the indices in further reflections, the method considers the facts described above. Based on the values derived after the 2nd iteration – $k_{c,2}$, the countries' diversity is ranked as follows: Germany, Sweden, Korea, South Africa. Here, the method takes into account that Korea manufactures a product found only in diverse countries (as Germany), while South Africa exports a ubiquitous product found in both diverse and non-diverse countries.

The method works similarly with the products. By incorporating the information about the countries exporting a specific product, it adjusts its score iteratively. If a good is rather simple to produce, but found in few countries, for example, diamonds in Botswana, it will get low ubiquity score in the first iteration. However, after a couple of further iterations, the method will account for both the diversification of the other countries that export diamonds together with Botswana, as well as consider the other goods in their export baskets, in addition to diamonds. In case of our example, the method will look at the diversification and exports structure of other African countries. As these countries are mostly poorly diversified, and the other products they export are far from being complex, the method will adjust the score accordingly.

As a result, this technique is able to identify which country has a more sophisticated productive structure, even when the number of goods exported is equal. It is also able to assess which product is more complex, even when the number of countries exporting it is similar.

For our analysis, we use the country-specific measures such as $k_{c,0}$ and $k_{c,1}$, a country's diversification and the average ubiquity of its exports correspondently, as they are the easiest to interpret. In addition to this, we also employ the Economic Complexity Index in our analysis.

ECI Index Calculations

The Economic Complexity Index for the countries is obtained by increasing the number of iterations until no any new information can be extracted (i.e., the relative positions of the countries in ECI ranking stay unchanged). For instance, in Hidalgo and Hausmann (2009), n=18 iterations is used for calculating the ECI.

In our study, we do not calculate the ECI ourselves, but take it from the dataset provided by the Observatory of Economic Complexity (2018).

Empirical Model

We estimate the effect of economic complexity on growth volatility using a panel regression with time- and country-fixed effects, with the robust errors adjusted for heteroscedasticity and autocorrelation.

We divide our 20-year sample period (1995-2015) into four 5-year subperiods and calculate the average values of the explanatory variables and the sample standard deviation of GDP growth rate.

For the regression, we standardize some variables (GPC, CRED, SPEN, OPEN, UBI). We do not perform any transformations with ECI and institutional variables as they are already transformed in the raw dataset. The diversification measure – number of products – stays untransformed as well.

Eventually, we first estimate the following equation:

$$GDPvol_{it} = \beta_0 + \beta_1 Diversification_{i,t} + \beta_2 Ubiquity_{i,t} + \beta_4 ECI_{it} + X_3 Controls_{it} + \mu_i + \eta_t + u_{it},$$

where $GDPvol$ is the measure of volatility, $Diversification$ and $Ubiquity$ are the null and first iteration terms calculated as explained above, *ECI* is the Economic Complexity Index and $Controls$ is a vector of control variables. μ_i and η_t denote country and time fixed effects, and u_{it} is the residual. We separate *ECI* from *Diversification* and *Ubiquity* measures due to multicollinearity.

We remove two outliers from the sample, which experience volatility higher than 10% within a studied time period.

As the countries in OECD sample are quite homogenous, some of the control variables are correlated. In our regression analysis, we carefully decide which controls to include and look at the Variance Inflation Factor (VIF) to avoid multicollinearity. As many institutional control variables are highly correlated, we leave only two of them in our regressions, namely *PV* and *RL*.

To capture different effects of both researched variables and controls on volatility, we selectively add interaction terms. Here, we also use VIF to test for multicollinearity.

We test different specifications of the model, adding and excluding the controls and interactions depending on their significance. We do that to test the robustness of the coefficients to the minor changes in particular specifications of the model.

4. Analysis of Results

Baseline Results

Our baseline results are the country- and time- fixed effects panel regressions, in which we separate ECI from its two structural components – diversity and ubiquity. The regressions with all three measures as explanatory variables do not yield meaningful results, because high correlation between ubiquity and ECI (-0.87) creates a problem of multicollinearity. By composition, the measure of complexity possesses the information from the ubiquity and diversity variables, providing a rationale for separating index into its two separate parts.

The baseline results are reported in Table 3.

Table 3. Baseline results of a fixed-effects panel regression

Variable	**(1)**	**(2)**	**(3)**	**(4)**
ECI	-3.20***	-3.18***		
DIV			0.0012	0.0024
UBI			3.42***	3.39***
Controls				
GPC	-0.93*	-0.59	-0.82	-0.38
OPEN	1.10***	1.10***	1.06**	1.09**
TOT	-16.95***	-17.32***	-15.18***	-15.43***
CRED	1.60***	1.50***	1.35***	1.16***
SPEN	-0.06	0.00	0.19	0.13
PV		0.14		-0.33
RL		-1.19		-0.98
Constant	6.03***	7.37***	5.84***	7.16***
Observations	127	127	127	127
Countries	33	33	33	33
R-squared	0.09	0.11	0.14	0.19

Note: Dependent variable is the volatility of a real GDP growth. Significance at the 1%, 5% and 10% levels are denoted respectively by ***,** and *. Haussman test results are reported in Appendix 4.

When separated, both ubiquity and ECI are significant at 1% in all of the model specifications, with or without inclusion of institutional variables. Moreover, the coefficients have similar absolute values, meaning that a one standard deviation increase in ECI has approximately the same effect on growth volatility as a one standard deviation decrease in ubiquity (apx. 3.2-3.4pp).

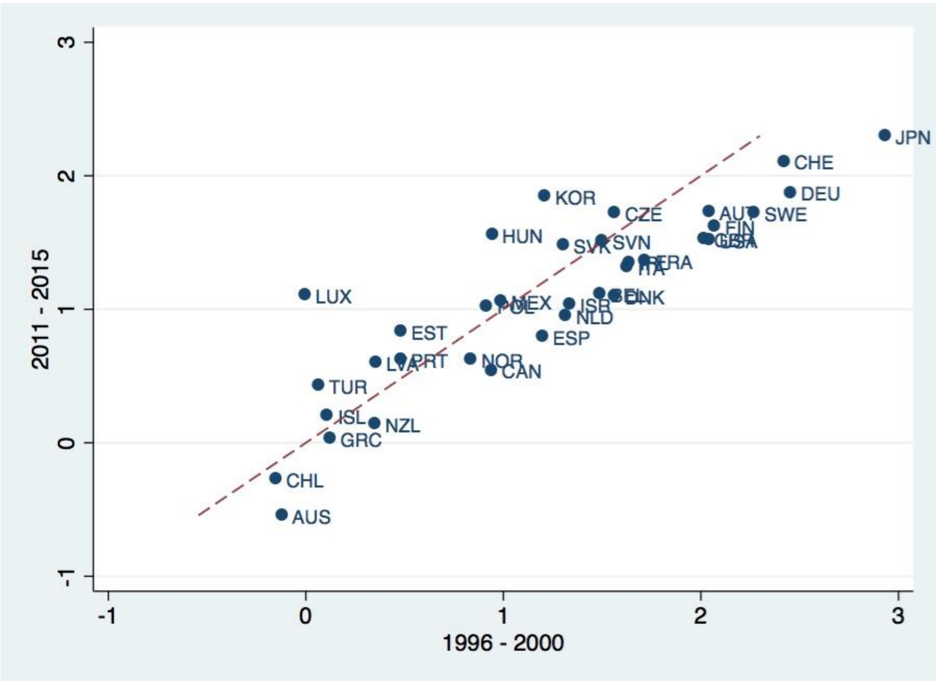
Keeping in mind that by construction of the ECI index it is impossible to decrease ubiquity without increasing ECI, and considering the insignificance of diversification variable, we can argue that it is, in fact, the ubiquity – and not the diversification – part of the ECI index which explains the volatility of growth. To affirm this claim, we will check the robustness of this result in the next sections.

The interpretation of displayed estimates is clear: we have quite strong evidence that the economies producing less ubiquitous products experience more stability in their growth. This finding is robust to the inclusion of institutional and macroeconomic variables as controls, as well as in line with the economic theory – the more sophisticated products are, the less exposed to the outside shocks their manufacturers, so that the economies specializing in them are more stable as well.

To understand the magnitude of the effect, let us give an example: a country which decreases its ubiquity by 1 standard deviation, will experience a 3.4pp drop in growth volatility. To put this into perspective, a one standard deviation drop in ubiquity would mean changing a product basket from the one similar to Slovakia to the one similar to Germany. That is why even minor changes in a product basket may drastically affect volatility.

In Figure 2, we see how the ECI for each country has changed over a period of more than 10 years. The countries located above the red line have increased their complexity, those which are below – decreased.

Figure 2. ECI development over time



Source: Created by the authors.

The first observation is the amplitude of a change: except for Luxembourg, South Korea and Japan, the countries do not to experience large rises or drops in the index value. This is mainly explained by the path dependence of a single country's production capabilities structure, amplified by the fact that the evolution of capabilities is a long-lasting time process (Balland & Rigby, 2017).

However, the path dependency should be treated carefully: a resource-based economy, which products are characterized by a high level of ubiquity – whether it is petrochemicals or diamonds, will not necessarily follow its natural resources path and experience the challenges such as "resource curse", also known as a "Dutch disease". In this sense, the path dependency should mean the building upon the existing capabilities. For instance, from mining and polishing of diamonds, Botswana might have moved into diamonds necklaces design and production. In most of the cases when we talk about "resource curse", we mainly imply countries relying considerably on their natural resources, while do forget about the countries, such as Norway, for example, which are resource-rich economies not heavily depending on their natural endowments. Thus, developing along a value chain, or in other words, vertically building on available set of capabilities is a plausible case. However, as Hidalgo and Hausmann (2009) specify, it is not an easy task as countries are prone to develop diagonally instead: in reality, only one third of countries harvesting sugarcane export confectionary as well, while the remaining two thirds employ people in cloth manufacturing. We argue that as a result of path dependency, time frame and the choices of specific countries, the ECI, and hence, its ubiquity part sees low dynamics as we observe in Figure 2.

Another observation relates to the direction of a change: as the graph depicts, the countries located below a red line are those which experienced a decrease in the ECI value, while those above – an increase in it. Apparently, fewer countries encountered a positive incremental change, with the largest ones observed in Luxembourg, South Korea and Hungary.

While we are not going to dig deep into the possible reasons standing behind it, we are still able to hypothesize that this can be driven by the fact that developing countries replicate previously highly unique goods (and hence, highly sophisticated ones) that are mainly present in developed countries faster than the new products, requiring specific know-how knowledge and a set of distinct capabilities, are developed.

The other control variables have the effect predicted by economic theory.

The positive effect of openness on GDP volatility is in line with the prevailing literature (Stiglitz, Islam, & Easterly, 2000; Kose, Prasad, & Terrones, 2003). There are several theories which support the observed relationship. As discussed previously, Giovanni and Levchenko (2009) find the evidence for the three possible channels that transmit the effect of trade openness into a higher output volatility. But their main conclusion is that the countries become more specialized as they open to international trade.

Given our sample of developed countries and their high trade openness, can we indirectly infer that we should expect their exports structure to become less diversified?

On the one hand, the developed countries are well-diversified – the fact which finds support in our sample as well: the average diversification of OECD countries is almost three times higher comparing to non-OECD members. On the other hand, as Haddad et al. (2011) conclude, a higher degree of diversification should in fact predict a *negative* effect of openness on income volatility, providing an enhanced opportunity for the risk sharing schemes. We do not find any evidence for this in our sample. Thus, theoretically, it might be the case that while developed countries still have considerably larger diversification comparing to developing countries, this value do not necessarily increase or stay the same, but can also face a downward trend.

The effect of private credit flows on economic volatility was also previously researched by Easterly, Islam, and Stiglitz (2000). They find that more credit in the economy stands for less volatility, but the relationship is non-linear. "While developed financial systems offer opportunities for stabilization, they may also imply higher leverage of firms and thus more risk and less stability… As the financial system grows relative to GDP, the increase in risk becomes more important and acts to reduce stability" (p. 202).

In our models, we observe that one standard deviation raise in private credit to GDP ratio (an equivalent of apx. 80pp) increases the growth volatility by 1.2pp (eq. 4, Table 3). All OECD counties have developed financial systems, so our positive estimate for credit variable might relate to the amplified risks that countries have when private firms borrow excessively. Moreover, a developed financial system reinforces the business cycle fluctuations as the access to funding can be pro-cyclical: it is easier during the peaks and worse during the troughs.

Terms of trade volatility has near-zero correlation with income volatility and its negative coefficient contradicts economic theory. But it is still significant in our model and adds to the explanatory power of it. Here, we might be dealing with a so-called suppressor variable, which is often encountered in quantitative research. While seemingly having no effect on the dependent variable, the terms of trade volatility is correlated with the independent variables, and suppresses the unrelated variance in them, thus increasing the explanatory power of the whole model.

The institutional variables are insignificant in all of the model specifications. We hypothesize that it happens due to their low variance in our sample. For example, PV – political stability and absence of violence – captures the presence of terrorism, riots and civil wars. Majority of the OECD countries are politically stable, and consequently, have very little within- and between- variance. A sample incorporating countries with different levels of institutional development would be more suited for analyzing their effects.

Robustness Check: Different Measures of Diversification

Numerous previous research shows that export diversification is a significant determinant of income volatility (Jansen, 2004; Agosin, Alvarez & Ortega, 2012). While we find it to be insignificant, we acknowledge that our measure is rather basic. We use the number of products exported with a comparative advantage as a proxy for diversification. By that, we omit the information about the products which may be sophisticated, but are exported either in small quantities or their share in a country's export basket is very close to the average share in the global market.

To check the robustness of our results, we obtain three different measures of diversification from UNCTAD: the number of products exported (DIV1), concentration index (DIV2), and diversification index (DIV3) (see Appendix 1 for the definitions). The data is available for all the OECD countries, so the number of observations stays unchanged.

Table 4. Robustness checks with different measures of diversification

Variable	(1)	(2)	(3)	(4)
UBI	3.39***	3.25**	3.34**	3.38**
Diversification				
DIV	0.0024			
DIV1		-0.034		
DIV2			2.64	
DIV3				0.38
Controls				
GPC	-0.38	-0.48	-0.59	-0.48
OPEN	1.09**	1.18***	1.02**	1.06***
TOT	-15.43***	-15.44***	-16.70***	-15.81***
CRED	1.26***	1.45***	1.30***	1.26***
SPEN	0.13	-0.10	0.18	0.12
PV	-0.33	-0.41	-0.29	-0.33
RL	-0.98	-0.72	-0.72	-0.89
Constant	7.16***	15.59***	6.30***	7.37**
Observations	127	127	127	127
Countries	33	33	33	33
R-squared	0.21	0.21	0.21	0.21

Note: Dependent variable is the volatility of a real GDP growth. Significance at the 1%, 5% and 10% levels are denoted respectively by ***,** and *.

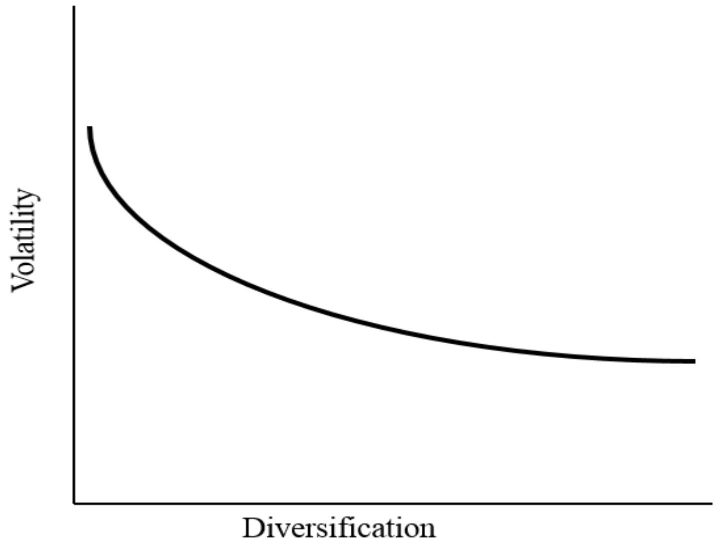
We find that in the baseline regressions all three measures are insignificant and fail to alter the coefficients of the other control variables: the openness and private credit variables are still significant; the numerical effect of ubiquity stays around 3pp within 4 model specifications.

Before arguing that it is indeed the ubiquity of exports and not their diversification that explains income growth volatility, we look at another branch of literature which explores a non-linear nature between product diversification and economic development.

In a seminal paper, Imbs and Wacziarg (2003) uncover a U-shaped relation between diversification and GDP per capita: at the first stage, poor countries reach the new markets, grow richer and diversify their economies. But at a certain point, the trend reverses, and the countries start to specialize again by focusing on the products where they are most competitive (see Appendix 2).

We hypothesize that in addition to income and diversification, a non-linear relation could also exist between volatility and diversification. While it is difficult to argue that high diversification is associated with high volatility, it is possible that there are diminishing returns to diversification: the effect of 10 more products exported could be different for countries currently exporting 20 or 200 products (Figure 3). Similar to portfolio theory and diminishing returns to asset diversification, adding one more product to your export basket carries less benefit when your basket is already highly diversified.

Figure 3. The diminishing returns to diversification



Source: Created by the authors.

We estimate the baseline regressions adding squared term for every measure of diversification. The results are reported in Table 5.

We find that only one measure of diversification (DIV3) shows significant effect on volatility at 5%. DIV3 measures how close a country's trade basket resembles the world trade (from 0 to 1) – a higher value means the country's exports are less alike the world trade. So, in our results, a 0.1 increase in DIV3 for a country with the index value of 0.5 will reduce volatility by approximately 1.3pp.

This result should be treated with caution as our sample is not diverse enough, comprising of OECD countries only. Most of the countries have a high level of diversification, so research incorporating poor and developing countries will be more appropriate for proving if there is indeed a non-linear dynamic between diversity and volatility.

Table 5. Robustness checks with different measures of diversification (a non-linear estimation)

Variable	**(1)**	**(2)**	**(3)**	**(4)**
UBI	3.07**	2.73**	3.01**	3.08**
Diversification				
DIV	0.0006			
DIV_SQ	-0.000009			
DIV1		0.68		
DIV1_SQ		-0.00015		
DIV2			-0.47	
DIV2_SQ			8.11	
DIV3				-26.35**
DIV3_SQ				26.47**
Controls				
GPC	-0.39	-0.60	-0.58	-0.86
OPEN	0.95**	1.05***	0.85**	0.77**
TOT	-15.03***	-15.46***	-16.47***	-17.11**
CRED	0.76*	0.99*	0.81**	0.77**
SPEN	0.19	0.08	0.26	0.23
PV	-0.53	-0.51	-0.48	-0.62
RL	-0.95	-1.18	-0.74	-0.51
Constant	7.21***	-65.78	7.06***	13.17***
Observations	127	127	127	127
Countries	33	33	33	33
R-squared	0.24	0.26	0.24	0.22

Note: Dependent variable is the volatility of a real GDP growth. Significance at the 1%, 5% and 10% levels are denoted respectively by ***,** and *.

Robustness Checks: Countering Limitations

The method of measuring economic complexity using Hidalgo and Hausmann's technique has several limitations. The main criticism concerns proxying a country's production structure by using the export data only.

First, the method may underestimate the complexity of economies with large services sector. For instance, the countries like the UK, Luxembourg and Singapore have significant exports of financial services, which are not recorded in trade data, but are representative of many capabilities available.

Secondly, non-tradable sectors are excluded from consideration. Some countries may have developed strong capabilities in education, health care, construction, etc., but due to the absence of this information in ECI calculations, the complexity of economies relying on non-tradables is underestimated. Similarly, large economies, which produce complex goods for domestic consumptions and engage in relatively little trade (e.g., USA or Japan) may also have underestimated scores.

Thirdly, the availability of data constitutes another limitation. As we are aiming at investigating the volatility dynamics and divide the time span of 20 years in 4 periods, we should appreciate that 5-year intervals can be not sufficient for observing the "fundamental" income volatility and we might deal with coincidental volatility measures.

Another limitation relates to the prevalence of the global value chains in the modern economy. Most countries do not manufacture a product in full, but are responsible for a particular stage of production. That is why even if the country performs only the final assembly of a sophisticated product, a manufactured product still appears in the export records and overvalues a country's complexity.

All these factors overestimate the complexity of small open economies. A case in point here could be a comparison of Czech Republic and the USA. In 2011-2015, Czech Republic consistently had a higher ECI than the United States. While it is more likely that the US productive structures are more sophisticated than Czech ones, ignoring services and non-tradables as well as putting aside the high level of the US domestic consumption undervalues the true value of a country's complexity. Even more important, Czech Republic serves as a final assembly point for German car manufactures, thus the large part of high sophistication should be attributed to Germany, not Czech Republic itself.

In light of the discussed limitations, we add several non-trivial control variables, which were not previously researched in the context of income volatility, but are specifically chosen to address the shortcomings of economic complexity methodology.

We use three new control variables to address the limitations: *the trade in services as a percentage of GDP, Nominal GDP and foreign value added (FVA) in gross exports.* Due to data limitations, the full sample regression can be only performed with the *Nominal GDP* variable, while the same sample becomes truncated with two other measures.

Table 6. Robustness check with the new control variables

Variable	(1)	(2)	(3)	(4)	(5)	(6)
ECI	-2.61***		-3.94**		-3.74***	
DIV		0.0002		-0.009		0.01*
UBI		2.77***		5.14***		4.2***
Controls						
GPC	-0.23	-0.12	-0.67	-0.89	-0.46	0.35
OPEN	0.91**	0.88**	1.41*	1.18	1.75***	2.16***
TOT	-16.25***	-14.87***	-26.77***	-23.61***	-17.92***	-15.92***
CRED	1.41***	1.17***	1.62***	1.33**	1.46**	0.98**
SPEN	-0.43	0.34	-0.06	0.26	-0.88	0.25
PV	0.21	-0.18	-0.14	-0.61	0.43	0.04
RL	-0.46	-0.24	0.11	0.88	-0.94	-1.05
New						
GDP	-7.31***	-7.32***				
FVA			-0.02	0.04		
SERV					1.36	1.03
Constant	6.66***	6.79***	7.61*	8.96**	7.68***	6.41***
Observations	127	127	95	95	107	107
Countries	33	33	33	33	33	33
R-squared	0.09	0.09	0.08	0.12	0.12	0.15

Note: Dependent variable is the volatility of real GDP growth. Significance at the 1%, 5% and 10% levels are denoted respectively by ***,** and *.

Further Robustness Checks

To ensure the validity of our results, we perform three additional robustness checks.

First, we cross-check our results by using the HS 4-digit classification of exports dataset, obtained from The Observatory of Economic Complexity. These data provide a more detailed look at a country's economic complexity.

Secondly, we generate interaction terms of ECI and ubiquity measures with GDP per capita and openness, hypothesizing that economic complexity matters more for open countries and that economic complexity loses its importance as the countries grow richer.

Finally, we perform a simple first difference regression. This model does not include time- or country-fixed effects and treats all the differences similarly. Thus, we use simple multiple regression as for cross-sectional data. Due to a number of missing values, the number of observations drops significantly.

Neither of these robustness checks challenges our baseline model conclusions. In all of the regressions, ubiquity and ECI variables stay significant with no major alterations in coefficients (see Appendix 3).

Policy Implications

In our research, we outline that the countries which have higher economic complexity – and possess more capabilities – are expected to benefit from low income volatility. The development of those capabilities is shown not only with regard to a higher stability of income growth, but also associated with a larger GDP per capita and lower income inequality. A logical question here is how to acquire those capabilities.

One of the most common, yet controversial ways to do this is the industrial policy. Pack and Saggi (2006) define it as "any type of selective intervention or government policy that attempts to alter the structure of production toward sectors that are expected to offer better prospects for economic growth than would occur in the absence of such intervention" (p. 267). In the past, these policies included subsidies to developing industries, trade protectionism, import-substitutions strategies, R&D support, etc. In fact, these are the policies that attempt to change a set of capabilities in the economy as well.

In this section, we discuss the theoretical arguments in favor of industrial policy, look at the opposing views of its effectiveness relying on the real case examples, and finally, present the current prevailing views among major policymakers.

The most important theoretical argument underscores the existence of market failures and a need to correct them through a particular policy. Hausmann and Rodrik (2003) argue that the entrepreneurs, who take risks by introducing new products to the market, provide great social value by discovering industries in which a country has a competitive advantage – the process known as a cost discovery. Yet, they capture little share of the value as imitators flood the market soon to reap freshly created benefits. As a result, "entrepreneurship of this type – learning what can be produced – will typically be undersupplied, and economic transformation delayed" (p. 4). In this case, the complexity will remain the same or even deteriorate, with no new capabilities being acquired.

To illustrate this, Hausmann and Rodrik (2003) compare Latin American countries with South Korea. While Latin American entrepreneurs had few incentives to discover new industries in 1980-1990s in the absence of industrial policy, their Chinese and Korean counterparts had plenty of government support and discovered new industries which later became the backbone of their economies.

Thus, intervention is needed to "encourage entrepreneurship and investment in new activities ex ante, but push out unproductive firms and sectors ex post" (p. 32). The authors endorse, for example, public sector credit to innovative firms for shifting part of the risk from the innovators. But they caution that if a firm turns out to be unproductive, it should be allowed to fail.

While Hausmann and Rodrik (2003) only propose a theoretical model supported by anecdotal evidence, Klinger and Lederman (2006) test the market failure hypothesis empirically. They find that there are positive spillovers from discovering that a new product can be exported competitively. Their results suggest that it is beneficial to support experiments in new sectors, but after first-movers appear, do not erect barriers to protect them.

Another question to addresses is how to properly determine which industries need government support. Lin and Chang (2009) provide an insight into the specifics of industrial policy. In a debate paper, taking a neoclassical point of view, Lin argues that the countries must develop the capabilities in areas in which they already possess a comparative advantage. Chang, opposing Lin, believes that the countries need to defy their comparative advantages first and jump into the industries in which they do not have any expertise yet. He acknowledges that "[inputs] still cannot be combined into an internationally competitive firm overnight because they actually need to be put through a (potentially very lengthy) learning process before they can acquire all the necessary technological capabilities" (p. 491), but points at the successful examples of Japan's automobile industry, South Korea and Nokia.

In this debate, Hausmann et al. (2011) sides with Lin. He writes: "Countries are more likely to succeed in this agenda if they focus on products that are close to their current set of productive capabilities, as this would facilitate the identification and provision of the missing capabilities" (p. 57).

While easy in theory, industrial policy encounters problems in practice. There are two main objections to state intervention. The first one is the notion that "governments cannot pick winners". The government might continuously choose wrong industries to support and in this case, will harm its own budget by wasting taxpayers' money. Secondly, the appropriation of resources through government is a clear way to corruption and rent-seeking.

The empirical work only adds confusion. The proponents of the industrial policy mainly rely on the case evidence from developing countries, underlining the successes of Japan, South Korea and Taiwan (Chang, 1993; Rodrik, 2004). The opponents mostly perform cross-sectional studies, finding little or negative effect on Total Factor Productivity (TFP), and arguing that other variables may have been responsible for a rapid development in selected states. They also point at the failure of the import-substitution industrialization in Latin America and unsuccessful attempts of developing new industries in Sub-Saharan Africa (Lawrence & Weinstein, 2001).

The examples from developed countries, the focus of our study, are multiple as well. Carefully designed industrial policy may boost innovation and development of new capabilities without harming market forces. While the OECD members certainly rely less on the government intervention in the presence of strong institutions and developed financial system which partly correct the market failures, they nevertheless often turn to industrial policy as a tool to facilitate further development (Buigues & Sekkat, 2009).

The empirical evidence on the use of government intervention to protect key sectors of the economy starts with the British Empire's tariffs on cloth in the 17th-18th centuries. Supporting the infant industry, Britain was able to develop a significant textile sector, which later became a source of major innovations placed at the center of industrial revolution (Chang, 2002).

A good example of capabilities development and their further spread across the economy is the United States in the 20th century. With active investing in military technologies and science (e.g., NASA), the capabilities developed in physics and engineering were at the forefront of technological revolution of the late 20th century. Looking at the products of the powerful market players such as Apple and Google or various biotech, start-up and consumer companies, those are based on the technologies once funded by the government (Mazzucato, 2015). That is exactly how the know-how spillovers work and why continuous accumulation of capabilities implies higher growth and less volatile economy.

The current industrial policy of the OECD countries resembles the "new industrial policy" advocated by Rodrik (2004). The EU countries champion free trade and are engaged in very little direct support of domestic industries. At the same time, the government is engaged into infrastructure projects as to support and promote innovation. EU structural funds, R&D spending and investments in education are all the examples of indirect facilitation of the new capabilities creation.

The “new industrial policy” is actively supported by OECD (2012) and European Commission (2014). These types of policies abandon the traditional instruments such as subsidies, tariffs, or state ownership and are better suited for the modern globalized world. They focus on helping in building a stimulating environment for private development (infrastructure, coordination, general strategy). Suggestions of Rodrik (2004), who first introduced it, and further contributions can be broadly summarized as:

“Industrial policy should:

- Target activities and broad sectors, never firms;
- Prevent conservative path-dependent decisions;
- Create new comparative advantages and help developing countries to diversify;
- Favour competition;
- Benefit society as a whole, not just individual companies;
- Define a vision of which capabilities will provide competitiveness and growth in the next 20-30 years” (summarized from Aiginger, 2014, p. 9).

The debate on the industrial policy effectiveness in the 20th century is still ongoing. The need to correct market failure and support infant industries is pitched against the argument for government ineffectiveness in doing that. Our results show that if those policies are indeed effective in capabilities development, they will reduce the volatility of those countries’ GDP. The other researchers prove that this will also increase GDP per capita and reduce income inequality. The new industrial policy, with a soft role of government in provision of infrastructure, institutions and strategic steering may be the answer which maximizes the benefits of intervention and minimizes the costs.

5. Conclusions

Recent developments in international trade provided a novel method for a quantitative estimation of capabilities accumulated in a country. In light of a newly developed index of economic complexity, the role of capabilities has already showed its great importance in relation to GDP and income inequality. Given a significant persistent impact that business cycle volatility has on a long-term growth trend, a question to ask is whether available set of capabilities a country possesses can affect its income volatility and make it less exposed to exogenous shocks. This paper looks at the determinants of income volatility in OECD countries over the last 20 years and models a 5-year volatility in two specifications: as a function of a) Economic Complexity Index and b) exports product diversity and ubiquity, in conjunction with a set of control variables.

The main finding of the paper relates to one of the two integral components of ECI: the ubiquity of a country's products. We find that economic complexity has a significant negative effect on output volatility, but also are able to conclude that this effect is attributable to the ubiquity part of the index. Thus, previously considered to be a good predictor – diversification – is irrelevant in our research. Our finding is robust to different model variations and the alternative choice of trade data. We argue that a set of capabilities a country has, measured by its complexity index, affects income volatility.

Our findings are relevant to the countries seeking economic stability and could guide the industrial policy in a country. While this is largely out of scope of our study, we still provide some discussion on the effectiveness of government support of complex industries. At the same time, we acknowledge that our main limitation is the homogenous sample of OECD countries. A research incorporating developing countries would be better suited for a more comprehensive discussion on policy implications.

Another branch of research could employ an action-orientated approach. While by now there is plenty of evidence that economic complexity matters, it is still an open question which specific structural reforms are the most efficient in growing the number of capabilities.

Finally, the limitations of the methodology, mainly concerning global value chains and the services sector should be tackled. In this respect, a more accurate proxy for the economy's production structure, replacing currently used exports figure, can be of a high relevance.

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7. Appendices

Appendix 1. Definitions of Diversification Measures **(UNCTAD, 2018)**

DIV1 – Number of products exported (or imported) at the three-digit SITC, Rev. 3 level.

DIV2 – Concentration Index (Herfindahl-Hirschmann Index)

$$H_j = \frac{\sqrt{\sum_{i=1}^{n} \left(\frac{x_{ij}}{X_j}\right)^2} - \sqrt{1/n}}{1 - \sqrt{1/n}},$$

where

H_j = country or country group index
x_{ij} = value of export for country *j* and product *i*

$$X_j = \sum_{i=1}^{n} x_{ij}$$

and n = number of products (SITC Revision 3 at 3-digit group level).

DIV3 – Diversification Index

$$S_j = \frac{\sum_i \left| h_{ij} - h_i \right|}{2},$$

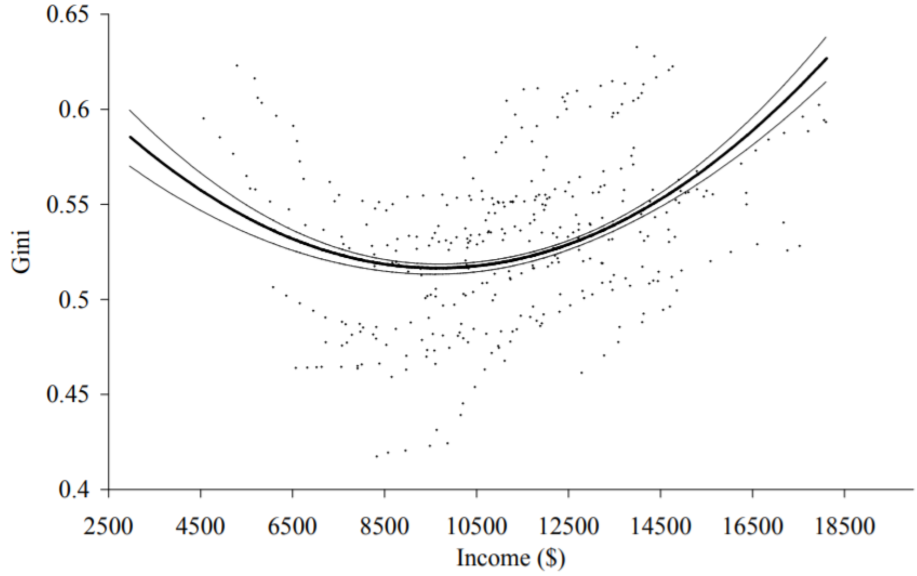
where

h_{ij} = share of product *i* in total exports or imports of country or country group *j*
h_i = share of product *i* in total world exports or imports.

The diversification index takes values between 0 and 1. A value closer to 1 indicates a greater divergence from the world pattern.

Appendix 2. Diversification and Income

Figure 4. Stages of diversification



Source: Adapted from Imbs and Wacziarg (2003).

Appendix 3. Further Robustness Checks

Table 7. Robustness checks with export classified according to Harmonized System (see Table 3 for comparison)

Variable	**(1)**	**(2)**	**(3)**	**(4)**
ECI	-2.54*	-2.45*		
UBI			3.80***	3.88***
DIV			0.006	0.0046
Controls				
GPC	-1.35***	-1.02**	-1.09**	-0.66
OPEN	0.97**	0.96**	1.02**	1.09**
TOT	-17.44***	-17.64***	-16.50***	-16.76***
CRED	1.32***	1.17***	1.15***	0.93***
SPEN	0.31	0.29	0.05	-0.10
PV		-0.23		-0.63
RL		-0.82		-0.74
Constant	5.24**	6.41***	5.96***	7.42***
Observations	127	127	127	127
Countries	33	33	33	33
R-squared	0.18	0.21	0.19	0.22

Notes: Dependent variable is the volatility of a real GDP growth. Significance at the 1%, 5% and 10% levels are denoted respectively by ***,** and *.

Table 8. Fixed-effects panel regression with interaction terms

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
ECI	-3.23**	-3.17**	-3.19**			
DIV				0.007	0.002	0.002
UBI				3.29***	3.40***	3.39***
Controls						
GPC	-1.03	-0.59	-0.65	-1.34	-0.38	-0.38
OPEN	1.03**	1.04**	1.12***	1.06**	1.38***	1.09**
TOT	-18.03***	-17.41***	-17.19***	-15.47***	-15.07***	-15.43***
CRED	1.32***	1.51***	1.48***	0.96**	1.07***	1.17***
SPEN	0.02	0.01	0.41	0.07	0.13	0.05
PV	0.04	0.14	0.13	-0.50	-0.34	-0.32
RL	-1.02	-1.19	-1.07	-0.35	-0.94	-1.01
Interactions						
GPC × ECI	0.58					
OP × ECI		0.05				
SPEN ×			-0.47			
GPC ×				-1.03*		
OP × UBI					0.26	
SPEN ×						-0.08
Constant	7.10***	7.37***	7.30***	4.85**	7.08***	7.21***
Observations	127	127	127	127	127	127
Countries	33	33	33	33	33	33
R-squared	0.16	0.14	0.14	0.24	0.22	0.22

Note: Dependent variable is the volatility of a real GDP growth. Significance at the 1%, 5% and 10% levels are denoted respectively by ***,** and *.

Table 9. Simple first-difference regressions

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
d.ECI	-8.16***	-8.15***	-7.96***			
d.DIV				-0.005	-0.006	-0.004
d.UBI				7.37***	7.47***	6.71***
Controls						
d.GPC	-0.29	-0.31	-0.23	-0.64	-0.50	-0.55
d.OPEN	0.88	0.88	0.78	0.68	0.66	0.57
d.TOT	9.2	9.24	9.35	18.27**	18.06**	19.18**
d.CRED	2.75***	2.75***	2.80***	2.24**	2.26**	2.29***
d.SPEN	1.48	-1.49	-1.42	-0.89	-0.88	-0.81
d.PV	0.34	0.34	0.35	-0.06	-0.04	-0.14
d.RL	-0.18	-0.14	-0.18	0.51	0.3	0.63
Interactions						
d.GPC × d.ECI		-0.59				
d.OPEN × d.ECI			-2.26			
d.GPC × d.UBI					2.50	
d.OPEN × d.UBI						5.87
Constant	-0.65**	-0.64**	-0.62**	-0.41	0.44	-0.36
Observations	94	94	94	94	94	94
Countries	33	33	33	33	33	33
R-squared	0.31	0.31	0.31	0.25	0.25	0.25

Note: Dependent variable is the first difference of volatility of a real GDP growth. Significance at the 1%, 5% and 10% levels are denoted respectively by ***,** and *.

Appendix 4. Hausman Test Results for Baseline Regressions

Figure 5. Hausman test results for Equation (2), Table 3

	Coefficients (b) fixed2	Coefficients (B) random2	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
eci	-3.180927	-.2088462	-2.972081	.7166321
z	-.5885412	-.3233768	-.2651644	.6132954
n_op	1.101171	.1682175	.9329533	.4508714
tot_vol	-17.31961	-8.063447	-9.256163	4.534211
n_cred	1.489515	.4746495	1.014865	.3640415
n_spen	.0024276	.0731504	-.0707228	.7395982
pv	.1430305	-.3552315	.498262	.5253183
rl	-1.19086	-.626942	-.5639183	.9185522
year				
2	-.6188466	-.5693197	-.0495269	.0808077
3	1.240965	1.670803	-.4298384	.1713222
4	-1.07818	-.4368587	-.6413215	.2609662

```
                b = consistent under Ho and Ha; obtained from xtreg
  B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test:  Ho:  difference in coefficients not systematic

              chi2(11) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                       =       28.78
            Prob>chi2 =       0.0025
```

Figure 6. Hausman test results for Equation (4), Table 3

	Coefficients (b) fixed4	Coefficients (B) random4	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
div	.0023602	-.0014815	.0038417	.0056831
ubi	3.391337	.3812336	3.010103	.7480481
z	-.3813369	-.2185277	-.1628093	.6586403
n_op	1.094781	.1491577	.945623	.4539514
tot_vol	-15.42532	-8.644665	-6.78065	4.406165
n_cred	1.162616	.4168511	.7457654	.3433506
n_spen	.1338284	.1001798	.0336486	.7163811
pv	-.3306699	-.4633035	.1326336	.5153234
rl	-.9842664	-.5667836	-.4174829	.9359828
year				
2	-.6512367	-.5906753	-.0605614	.0805167
3	1.392058	1.658144	-.266086	.1548478
4	-.9146646	-.4634804	-.4511841	.242807

```
                b = consistent under Ho and Ha; obtained from xtreg
  B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test:  Ho:  difference in coefficients not systematic

              chi2(12) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                       =       27.48
            Prob>chi2 =       0.0066
```