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Alternative Related Variety, Macroeconomic Factors and Diversification: Extractive vs. Non-Extractive Products

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Abstract

Export diversification is central to economic development. However, most resource-rich countries have failed to diversify. In understanding the determinants of diversification different strands of literature emerge. One view highlights the role of macroeconomic and trade-related factors linked to the Dutch disease, such as the real exchange rate, type of commodity, and international commodity prices (Agosin et al., 2012; Lederman & Maloney, 2007). Another perspective focuses on path dependence, primarily examining product relatedness measures. This perspective suggests that a nation's current productive capabilities shape its future production possibilities. The latter offers different advantages, such as analysing diversification at the product level instead of export concentration measures, which may be subject to several biases. However, this framework pays little attention to the determinants that shape a country's productive capabilities, enabling product relatedness. This paper introduces an alternative measure of product relatedness, adapting the approach proposed by Nomaler and Verspagen (2022) to encompass a broader set of unobservable characteristics. Our regression framework also integrates macroeconomic factors and relevant controls (i.e., international prices, exchange rate, energy and mineral dependency, GDP per capita) to explain diversification at the product level. We do this in a cross-country setting covering more than 5,000 products between 1995 and 2019; furthermore, we distinguish between different types of products to understand how variables affect diversification in non-extractive sectors vis-à-vis extractive sectors. Results demonstrate that our product relatedness measure is a robust predictor of diversification, especially in extractive sectors, which exhibit greater path dependence. However, macroeconomic factors, such as international prices, level of development, and commodity dependence, play a decisive role in explaining differences in diversification patterns, and excluding them may overestimate the predictive power of product relatedness.

Keywords: Export Diversification, Product Relatedness, Macroeconomic Factors, Extractive Sectors
JEL Codes: O11, F14, L78

1. Introduction

Diversification is central to economic development as it hinges upon a country's ability to produce a diverse range of technologically dynamic and sophisticated goods and services (Hausmann et al., 2005). Moreover, export diversification has been routinely promoted in countries rich in extractive resources as it is key in reducing the risks linked to commodity price fluctuations, among other prominent arguments. For instance, van der Ploeg & Poelhekke (2009) find that the positive direct effects of commodities on growth are trumped by the indirect negative effects of volatility associated with commodity prices).

Despite this, most countries rich in extractive resources have failed to diversify. For instance, from 1980 to 2010, it was observed that most oil and mineral producing economies experienced heightened export concentration (Ross, 2019). After prices fell in the mid-2010s, the economic hardships experienced by many extractive commodity exporters reignited the discussion about the relationship between extractive industries and diversification in order to understand better the conditions that promote it.

In understanding the determinants of diversification, or at least the inhibiting factors, different strands of literature emerge. On the one hand, one view highlights the role of macroeconomic and trade-related factors linked to the Dutch disease – which predicts that a surge in commodity exports drives up the real exchange rate hindering the development of manufacturing industries. Empirical studies in this vein have studied the relationship between export diversification and the real exchange rate with mixed results (Sekkat, 2016; Tran et al., 2017). Along the same lines, other scholars have looked into differences across commodities (Ahmadov, 2014; Lederman & Maloney, 2007) showing that export concentration is more strongly associated with oil producers and less so in mineral and other primary commodity exporters.

On the other hand, the evolutionary economic geography literature emphasizes that a country can more easily diversify into new products related to its existing products because such new products share resources, knowledge, and capacities similar to those that it already possesses (Boschma & Capone, 2015). In this view, thus, the production structure of a country is affected by its historical productive structure which follows a path-dependent process that, in turn, is underpinned by the relatedness among its products (Hidalgo et al., 2007).

Nonetheless, traditionally the related diversification approach has been critiqued due to the limited attention it has given to other factors which affect relatedness among industries, such as institutions, infrastructure, and the combination of factors of production (Boschma & Capone, 2015; Guo & He, 2017).

Additionally, there are other macroeconomic factors which could play a major role in the development of a country's capacity to diversify, such as the real exchange rate appreciation and global commodity prices. As initially explained by Krugman (1987), a country's capacity to produce a good is not exogenously given but instead evolves through a learning-by-doing process in key sectors, such as manufacturing. Therefore, when there is a real currency appreciation (as a result of higher exports of a booming commodity), this results in longterm, learning-by-doing losses as labour and production factors concentrate in the booming sector and away from manufacturing. Moreover, higher commodity prices on their own may play a role in incentivizing the production of extractive commodities at the expense of diversifying into other sectors. For instance, the increment in extractive commodity prices in the 2000s coincided with a notorious rise in the number of mineral commodities export-dependent countries (UNCTAD, 2019). In short, there are theoretical and empirical foundations that suggest that the resources and overlapping capabilities that affect industrial relatedness are shaped by commodity price shocks and real exchanges movements.

In this paper, thus, we investigate diversification determinants using an alternative measure for product relatedness based on Nomaler and Verspagen (2022), which we will refer to generically as 'related variety' while integrating commodity prices and macroeconomic factors in the analysis. Related variety, like other relatedness measures at the product level, relies on the conditional probability measures which captures whether a country has a comparative advantage in a tradeable good given that it has it in another one. However, this measure also accounts for information concerning the products in which a given country does not have comparative advantage to capture a broader set of unobserved factors (e.g., weak capabilities, institutional and geographical constraints, etc.) that also affect diversification (Nomaler & Verspagen, 2022).

Namely, we investigate the following questions:

- How does related variety explain the creation of comparative advantage in non-extractive products vis-a-vis extractive commodities?
- How do macro-economic variables, i.e., the real exchange rate, mining price index, and commodity dependence, affect the probability of diversification in non-extractive products?

A basic approach to approximate the effect of related variety on diversification is the increment in the range of products that a country exports with comparative advantage. We expand this analysis by including exchange rates, commodity prices, commodity dependence, and other standard macro-economic factors that may impact diversification outcomes. The analysis thus sheds light on the mediating effect of the macroeconomic variables on the diversification processes for non-extractive products beyond path dependence as traditionally captured by relatedness measures.

The paper is structured as follows. Section 2 presents a brief overview of the theoretical and empirical literature on export diversification – especially with a focus on its link to natural resources. Section 3 presents the methodology and description of the data. Section 4 reports the results of the empirical analysis. Section 5 concludes and discusses possibilities for future research.

2. Theoretical and Empirical Background

There is an empirical literature that establishes that what countries export and how diversified those exports have important implications for a country's economic development (Hausmann et al., 2005; McMillan et al., 2014). Furthermore, in the case of resource-rich countries specializing in minerals and/or energy, export diversification is considered a key strategy to avoid price volatility, expand employment outside the resource sector, and prepare for resource depletion (Ross, 2019). Likewise, rising global efforts to reduce greenhouse gas emissions by consuming fewer fossil fuels make diversification among oil and gas exporters even more pressing.

Concerning the general economic benefits of diversification, several papers have identified a positive empirical association between export diversification and economic growth; this includes the work of Al-Marhub (2000), Klinger and Lederman (2006), and Hesse (2008). The latter two studies find that the relationship between export diversification and per capita income growth follows an inverted-U function, implying that countries get higher returns from diversifying their exports at lower levels of economic development than at very high ones. To explain the positive relationship between diversification and growth several scholars have provided theoretical underpinnings – typically linking diversification to innovative activity. Acemoglu and Zilibotti (1997) explain that diversification is an endogenous process that is the result of producers' investment in a wide range of 'risky' sectors. Hausmann and Rodrik (2003) expand on that idea: diversification is not merely the result of comparative advantage but countries' diversification of their investments into new activities. Namely, the entrepreneurial cost-discovery process that entrepreneurs face results in significant cost uncertainties when attempting to move into new goods. If they succeed in developing new goods, the gains will be 'socialized' due to knowledge spillovers but the losses from failure end up being private. This often leads to an under-provision of investments into new activities and a suboptimal level of innovation.

Nonetheless, from an economic evolutionary perspective, innovation – more often than not – is a matter of recombining old ideas into a new base (and very rarely, the creation of a completely new reality). Besides, innovation requires at least some level of knowledge that is tacit and context-specific, and therefore, hard to transfer across countries (Maskell & Malmberg, 1999). Thus, the productive structure and technological transformation of a country will tend to be highly path-dependent: what a country currently produces to a large extent dictates what it will be able to produce in the future (Dosi et al., 1990; Winter & Nelson, 1982).

Evolutionary economic geography literature builds upon the latter idea to explain diversification patterns: a country will produce (and export) new products largely similar to those it already produces. This is because producing such new products requires productive capabilities, i.e., resources, knowledge, and capacities similar to those that the country already possesses (Hidalgo et al., 2007). In this view, if we consider two products, the possibility of becoming specialized in one (given specialization in the other) depends on whether they require the same capabilities – in other words, it depends on whether those two products relate (or not) in terms of productive capabilities . Studies in this strand, have established that product relatedness[1] is a determinant of

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[1] This namely refers to the product relatedness measures developed in Hausmann and Klinger (2007) and Hidalgo et al. (2007) which have been widely employed in that type of empirical analysis. Yet there are other measures capturing how

diversification – either at national or regional levels (Boschma et al., 2012; Hausmann & Klinger, 2007; Neffke et al., 2011). They show, in other words, that diversification patterns are highly path dependent. Nonetheless, as pointed out in Boschma and Capone (2015) these studies do not explain differences in the diversification patterns across countries. Indeed, product relatedness measures employed in such studies (i.e., Hausmann & Klinger, 2007) rely on export co-occurrence to proxy for similar productive capabilities; but they do not explain *why* those goods are exported in some countries and not in others (Content & Frenken, 2016).

To learn more about the determinants of the direction and intensity of the diversification processes, more recent empirical frameworks have then incorporated the role of institutions and governance (e.g. Boschma & Capone, 2015; He & Zhu, 2018), as well as global linkages, captured by imports, FDI, and/or trade liberalization (Alonso & Martín, 2019; He et al., 2018) to shed further light into explaining differences. Most of these studies, however, have focused on within-country determinants.

All in all, a knowledge gap remains concerning the factors that play a role in the emergence and development of productive capabilities and more specifically those that enable entrepreneurs to engage in innovation activities which ultimately leads to diversification. According to Lall (1992), a country's technological capabilities are determined by the interplay of general capabilities (e.g., human capital); institutions, and incentives stemming from competition, factor markets, and naturally, macroeconomic factors, such as price changes, exchange rates, credit and foreign exchange availability, political stability or exogenous shocks (e.g., terms of trade). The following paragraphs focus on discussing some of the macroeconomic (and other country) characteristics that have been empirically tested in previous studies.

As pointed out by several scholars (Agosin et al., 2012; Alsharif et al., 2017; Ross, 2019; Wiig & Kolstad, 2012), even though diversification has been prescribed as essential in boosting economic development, how countries can achieve this remains relatively understudied. Scholarly works on the determinants of diversification, however, have at least identified some inhibiting factors, such as natural resource abundance; but the role that key macroeconomic factors play, such as the real exchange rate, still is inconclusive.

For instance, Esanov (2012) using a panel random-effects framework covering the 1980-2006 period, finds that export concentration is positively related to the share of natural resources in total exports; contrariwise, the study suggests a negative correlation of concentration with investment and trade freedom but no correlation with trade openness, inflation, FDI, or quality of institutions. Ahmadov (2014) using an IV setup which looks at the 1970-2010 period, further confirms that diversification is negatively associated with countries rich in resources but that this result applies only to countries that are rich in oil, located in Africa or the Middle East, and that have autocratic regimes. No effects are found for human capital, trade openness, and quality of

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related productive capabilities of different products are; for instance, Franken et al. (2007) who look at the hierarchical classification of products by the SIC scheme.

government. Along the same lines, Bahar and Santos (2016), using a variety of non-resource export concentration indices for the period 1985-2010, find strong evidence that higher shares of natural resources are associated with lower non-resource export diversification. Finally, Alsharif et al. (2017) find that oil exports are negatively associated with diversification (in this case, measured by non-oil rents). These studies thus provide empirical evidence that the more a country depends on commodity resources the less likely it will achieve to diversify its basket of exports, in line with the outcomes predicted by the Dutch disease.

Other empirical studies have focused on the causal link between the real exchange rate and diversification. One reason for this is that currency exchange misalignments – namely overvaluation – is the main factor that explains export concentration according to the Dutch disease (Corden & Neary, 1982): Higher commodity prices in this model lead to an increment in commodity exports of the booming commodity sector leading to a real currency appreciation; this, in turn, reduces the competitiveness of other tradables in international markets, further pushing the economy into specialization in the booming commodity sector. The second reason for investigating the effects of real exchange rates on diversification is that some scholars (e.g., Rodrik, 2008) have suggested – against mainstream economic prescriptions – that currency undervaluation can promote diversification in weak institutional frameworks as it can act as a production subsidy plus a consumption tax on tradables.

Still, empirical evidence supporting the causal link between commodity/tradeable exports performance and the real exchange rate across countries is mixed. For instance, Sekkat (2016), using Granger causality tests and a GMM framework, finds evidence of some positive effect of undervaluation on the share of manufactures in total exports; yet currency misalignment (either over or undervaluation) does not affect exports concentration – a result that holds even when the sample was restricted to countries whose quality of institutions is considered low.

One explanation of why the link between real exchange rates and diversification remains unclear is because of the potential bi-directional causality and great heterogeneity among countries. Tran et al. (2017), based on Granger causality techniques on panel data from 1995-2013, find that the real exchange rate is a determinant of export diversification but in only three developing countries in their sample; yet for the whole sample of countries, it shows a two-way causality. They conclude the direction of real exchange rates to diversification is highly heterogeneous among developing countries. Furthermore, Agosin et al., (2012) use a GMM panel over the 1962–2000 period, and whereas they do not find significant effects of exchange rate overvaluation on diversification, they do find a negative effect associated with increasing terms of trade. They suggest that an increase in the price of the main exported commodity induces the reallocation of factors to that sector, reducing either the availability or increasing the costs of inputs for new products exports. The latter, thus, suggests that an increase in commodity prices may influence concentration not necessarily via real exchange movements but also due to factor reallocation. This also resonates with relatively recent commodity price trends. As pointed out in UNCTAD (2019), rising commodity prices between 1998 to 2017 contributed to changes in the export composition of commodity exporters – changes which typically consisted of further export of concentration in oil and, especially, mineral exports[2] (UNCTAD, 2019).

Considering the discussion above, the current analysis combines empirical literature which looks at diversification at the product level, and macroeconomic variables, namely real exchange rate, prices, and export dependence – given their relevance for understanding the dynamics of extractive and non-extractive exports. Looking at product level diversification in the empirical framework instead of export concentration – which is a measure that can be easily contaminated by price fluctuations (Alsharif et al., 2017)[3] - and using an alternative measure for relatedness, this study sheds further light on how path dependence predicts diversification in non-extractive and extractive goods.

A final consideration here is that diversification in extractive commodities has received empirically little attention in recent years for obvious reasons (the empirical evidence is a logical deterrent not to go in that direction). Yet, not a lot is known on the determinants of this process: certainly, being able to diversify into extractive commodities is to a large extent 'God-given', but modern extractive resource industries often demand non-trivial technological, economic, political, and social processes (Ville & Wicken, 2012). Therefore, understanding how path dependency and macroeconomic factors play out for extractive products diversification vis-à-vis non-extractives may also contribute to understanding the overall dynamics of path dependency and diversification processes.

3. Methodology

3.1 Related Variety Calculation

We use a probability-based relatedness measure for related variety to account for diversification potential as developed in Nomaler and Verspagen (2022). Diversification in this context is defined as the increment in the number of products that a country exports with revealed comparative advantage (RCA)[4]. Akin to other commonly applied product relatedness measures, the measure we employ builds upon the idea that a country's ability to develop new products in the future is – at least in part – determined by its present specialization structure.

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[2] Commodity-dependent countries increased from 92 in 1998–2002 to 102 in 2013–2017. Yet, countries dependent upon agricultural exports went from 50 to 37 between these two periods. In contrast, mineral-dependent countries increased from 14 to 33, and the number of energy-dependent countries rose from 28 to 32. According to the classification of UNCTAD (2019), a country is commodity-dependent when more than 60% of its total exports are comprised of commodities.

[3] Measuring diversification, can be problematic when looking at commodities. As pointed out in Alsharif et al. (2017), export concentration (i.e., commodity exports as a share of total exports) in the presence of a negative price shock could reflect a "pseudo diversification" process rather than genuine changes in the export composition.

[4] The method presented is an adapted version to method employed in the development of the Upgrading Triangle presented in Annex 7.2 of the Greater Mekong Subregion 2030 and Beyond Report (ADB, 2021).

First, $\boldsymbol{X}$ represents a binary matrix of RCA[5] with dimensions $m \times n$, where m corresponds to the number of products and n is the number of countries. A typical element in $\boldsymbol{X}$, represented by x_{ij}, takes a bivariate value, following the definition of RCA originally proposed by Balassa (1965):

$$x_{ij} = \begin{cases} 1\ if\ RCA \geq 1 \\ 0\ otherwise \end{cases}$$

Further, a conditional probability (product-by-product) matrix, $\boldsymbol{G}$, is defined in the following manner:

$$\boldsymbol{G} = (\boldsymbol{XX'})/s$$

where $\boldsymbol{X'}$ represents a transposed matrix and s is the vector containing the row-sum of $\boldsymbol{X}$ (i.e., the number of total exported products with comparative advantage by a given country)[6]. $\boldsymbol{G}$ thus is a non-symmetrical matrix with $m \times m$ dimensions where a typical element, g_{kl} , indicates the probability of a having a comparative advantage in product k conditional upon having comparative advantage in product l, based on the information provided in $\boldsymbol{X}$.

The resulting matrix already provides rich information about the probability of developing advantage. However, we also incorporate information that captures the lack of comparative advantage in a particular product to estimate better the probability that a country has a comparative advantage in another one.

Considering this, we define the matrix $\boldsymbol{Z} = \boldsymbol{O} - \boldsymbol{X}$, in which $\boldsymbol{O}$ is a matrix with only ones and with $m \times n$ dimensions. The elements of the matrix $\boldsymbol{Z}$ thus are defined as follows:

$$z_{ij} = \begin{cases} 1\ if\ x_{ij} = 0 \\ 0\ if\ x_{ij} = 1 \end{cases}$$

The corresponding conditional probability (product-by-product) matrix $\boldsymbol{H}$ is defined as:

$$\boldsymbol{H} = (\boldsymbol{XZ'})'/t \ = (\boldsymbol{ZX'})/t$$

where t represents the row-sum of $\boldsymbol{Z}$, i.e., the number of countries that export a given product with no comparative advantage. $\boldsymbol{H}$ is a non-symmetrical matrix with $m \times m$ dimensions where a typical element, denoted as h_{kl}, indicates the probability of having a comparative advantage in product k conditional upon not having comparative advantage in product l, based on the information provided in $\boldsymbol{Z}$. As the following step the

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[5] The RCA is calculated as:

$$RCA \ = \frac{E_{ij}/_{Ej}}{Ei/_{E}}$$

where E_{ij} denotes country j exports of product i and the summation over the relevant dimension is indicated by the absence of a subscript. It is also assumed that all countries export at least one product, and all products represent an export of at least one country.

[6] This also corresponds to the vector conceptualized as ubiquity in Hausmann and Hidalgo (2010) where the more countries export a product, the more ubiquitous the product is. Assumedly, higher ubiquity indicates that the capabilities required for producing such a product are more accessible to a large number of countries, and thus, less likely to be of higher complexity.

two conditional probability matrices are added up and scaled by m (the vector containing the total number of products exported by a given country):

$$\boldsymbol{K} = (\boldsymbol{G} + \boldsymbol{H})/m$$

$\boldsymbol{K}$, therefore, is a matrix of marginal conditional probabilities, with $m \times m$ dimensions. As a final step, we obtain a matrix comprised of the estimation of the probabilistic part of the RCA – contained in $\boldsymbol{X}$ - that results from the specialization profile of the country:

$$\boldsymbol{E} = \boldsymbol{X}'\boldsymbol{K}$$

Thus, $\boldsymbol{E}$ is a non-autonomous, (i.e., country-specific) matrix with dimensions $m \times n$ where a typical cell in $\boldsymbol{E}$, denoted as e_{ij}, indicates the probability that country *j* has comparative in product *i* conditional on the information about the whole range of products in which *j* has comparative advantage as well on the information about the range of products in which it does not.

To summarize, the **related variety** probability estimation in $\boldsymbol{E}$, is based on the underlying assumption that if two products, A and B, demand the same capabilities to produce them, these products are related to each other (and likely to be produced by the same country). If B requires capabilities that are very different from capabilities to produce A, these will be unrelated to each other (and unlikely to be produced by the same country), and thus have a lower related variety. Thus, the related variety probability estimation**,** based on the method proposed in Nomaler and Verspagen (2022), accounts for the information which captures similar capabilities, hence the *relatedness*, but also incorporates valuable information captured in the *absence* of those capabilities, which also affect the probability of a country to competitively produce a given product[7] and gain comparative advantage in the international market.

3.2 Econometric Approach

We begin with a modified version of the model proposed in Hausmann and Klinger (2006, 2007), where we employ the related variety probability estimation described in section 3.1. We use 4-year intervals (as opposed to 1-year intervals) to account for the time it takes to develop new products[8]. The resulting equation is then as follows:

$$RCA_{i,c,t+4} = \alpha + \gamma RCA_{\,i,c,t} + \beta E_{i,c,t} + \mu_i + \mu_c + \mu_t + \varepsilon_{i,c,t} \qquad (1)$$

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[7] To illustrate further why this is relevant, Nomaler and Verspagen (2022) show that the absence of specialization frequently coincides with the absence of some other specializations – a kind of *'anti-relatedness'* - which ultimately suggests some sort of competition in specialization.

[8] Several studies have opted for 5-year periods for this reason (see, for instance, Alonso & Martín, 2019; Boschma & Frenken, 2009). In particular, Alonso and Martín (Alonso & Martín, 2019) replicate the analysis with 4-year intervals and find no significant difference between the 5-year and 4-year periods. Since the panel is built based on a dataset that extends over 24 years, 4-year periods fit the time period while allowing for a reasonable length of time for product development.

where $RCA_{i,c,t}$ is a binary dependent variable which captures comparative advantage in product i in country c at the end of a 4-year period; and, $E_{i,c,t}$ is the related variety probability of product i in country c at the beginning of the period[9]. Subsequently, the parameter γ refers to the contribution of having comparative advantage in product i in country c at the beginning of the period to the probability of maintaining such comparative advantage four years later. In other words, it captures the persistence of comparative advantage. Likewise, the parameter β captures the effect of $E_{i,c,t}$ on having comparative advantage at the end of the period. Finally, μ_i, μ_c, and μ_t refer to product, country, and fixed effects.

Equation (1) then estimates the probability of diversification: The dependent variable captures whether a given country has a comparative advantage (RCA $\geq$ 1) in a given product of any sort, i.e., extractive and non-extractive products. To compare how diversification differs among different goods (i.e., non-extractive and extractive), a second specification is included where the dependent variable represents if a country has comparative advantage (RCA $\geq$ 1) in a given non-extractive product. For this, the sample is restricted to non-extractive products. A third specification considers a dependent variable that captures if a country has comparative advantage (RCA $\geq$ 1) in extractive commodities. For the latter, the sample is restricted to energy, metals, and minerals commodities[10].

In order to distinguish how relatedness measures impact upon the probability of gaining advantage in a new product from the impact upon maintaining comparative advantage (or preventing abandonment) in goods already produced, equation (1) is expanded as in Hausmann and Klinger (2007). The resulting equation is:

$$RCA_{i,c,t+4} = \alpha + \gamma RCA_{i,c,t} + \delta\left(1 - RCA_{i,c,t}\right) \times E_{i,c,t} + \vartheta\left(RCA_{i,c,t}\right) \times E_{i,c,t} + \mu_i + \mu_c + \mu_t + \varepsilon_{i,c,t} \qquad (2)$$

where parameters δ and ϑ reveal the effect that related variety would have on gaining comparative advantage in a new product and in maintaining it after the end of 4 years, respectively. The term, $E_{i,c,t}$, is not included because it is collinear with the two interaction terms. We finally expand Equation (2) to include controls at the national level to account for the macroeconomic conditions and other controls, including commodity prices and real exchange rates, that, as hypothesized, may affect diversification efforts:

$$RCA_{i,c,t+4} = \alpha + \gamma RCA_{i,c,t} + \delta\left(1 - RCA_{i,c,t}\right) \times E_{i,c,t} + \vartheta\left(RCA_{i,c,t}\right) \times E_{i,c,t} + \theta X_{c,t} + \mu_i + \mu_c + \mu_t + \varepsilon_{i,c,t} \qquad (3)$$

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[9] The latter term specifically refers to a typical cell, e_{ij} , contained in the E matrix defined in the previous section.

[10] These includes all mining commodities classified under the HS2 codes 26 and 71 and energy commodities under HS4 codes 2709, 2701 and 2711. Energy products do not include any form of processed product.

where $\boldsymbol{X}$ is a matrix of controls which include: the log of the country-specific mining price index as developed by Deaton (1999); b) the log of real effective exchange rate (REER) index (2010 = 100)[11]; and the log of GDP per capita (constant 2010 US dollars). It also includes two dummies capturing extractive commodity dependence: countries categorized as metal-, ore- and mineral-dependent take the value of 1, and 0 otherwise. Similarly, countries categorized as fuel- and gas-dependent take the value of 1, and 0 otherwise. In this way, a country can be energy-dependent, *or* mining-dependent, *or* not dependent on either type of commodity (there is no overlap among energy and mining dependence dummies). Likewise, we include a variable to capture investment as a share of GDP.

While a linear probability model could a be good initial departure point[12], estimation by probit (with an analogous specification to Equations (1) to (3)) has several advantages due to the binary nature of the dependent variable, $RCA_{i,c,t+4}$. In particular, we employ the Chamberlain-Mundlak correlated random effects (CRE) probit model in order to ensure the consistency of parameter estimates when including fixed effects, and to provide a more accurate estimation of the magnitude of the marginal effects (Chamberlain, 1982; Wooldridge, 2010). This model allows to control for unobserved heterogeneity in a non-linear set up, and at the same time, it considers potential correlations of individual-specific effects (in this case, product-specific effects) with observed characteristics, e.g., estimated related variety probability measure. The CRE approach introduces the group-level mean of each of the covariates, $\overline{x_\iota}$, in the probit specification. Adding $\overline{x_\iota}$ to control for unobserved heterogeneity (equivalent to $\mu_i + \mu_c + \mu_t$ as done in Equations (1) to (3)) is intuitive as it allows us to estimate the effect of changing $x_{c,i,t}$ while holding country- and/or product-effects fixed (Wooldridge, 2002). The correlated random effects model is then given by:

$$P\left(RCA_{i,c,t+4} = 1 \middle| x_{i,c,t}\right) = \Phi[(\psi + \beta x_{i,c,t} + \xi \overline{x_\iota})\,(1 + \sigma_a^2)^{-1/2}] \tag{4}$$

where $x_{i,c,t}$ refers to a vector of observable variables at the product- and country-level described in equations (1) to (3), $\overline{x_\iota}$ is the group-level mean (i.e., country and/or product) of each of these variables[13]; and σ_a^2 is the variance for the part of the random effects not captured by the averages $\overline{x_\iota}$. Year, and energy and mining

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[11] This refers to the World Bank's definition of REER: the nominal effective exchange rate (a measure of the value of a currency against a weighted average of several foreign currencies) divided by a price deflator or index of costs.

[12] Previous empirical applications (e.g., Alonso & Martín, 2019; Hausmann & Klinger, 2007) have relied on a linear probability models (LPM) as this approach is less computationally intensive and the maximum likelihood with fixed effects is subject to incidental parameters problems when groups are small yielding inconsistent estimates (Greene, 2004). However, our sample allows for a large number of groups and the correlated random effects probit model circumvents the issue of incidental parameters problem (Wooldridge, 2010, 2019).

[13] The CRE specification in equation (4) incorporates a multi-way fixed effect approach which corresponds to the specifications in the LPM model. For this we employ product- and country-level mean terms (where group-level means are generated separately). Time-effects are incorporated in the model by including year dummy variables. In particular, we follow the routine suggested in the Chamberlain RE pooled MLE model described in Wooldridge (2010).

dependence dummies are included in $x_{i,c,t}$ but excluded in $\bar{x_i}$. Note that in this setup, if $\xi = 0$ we would obtain the traditional random effects probit model.

This CRE model is our preferred specification and so its analogous specification for Equations (1) to (3) are reported in the results section – although comparisons with linear probability based on the Hausmann and Klinger (2007) basic models are provided in the Annex[14]. We also run the model specifications separately for the $RCA_{i,c,t+4}$ of all products, $RCA_{i,c,t+4}$ for non-extractive products, and $RCA_{i,c,t+4}$ for extractive commodities. In all specifications, standard errors are clustered at the country level.

3.3 Data

To calculate RCAs and related variety measures described in Section 2, we employ bilateral trade data from the BACI 2021 dataset that covers the 1995-2019 period with data collected for more than 5000 products and 220 countries. The BACI 2021 database constructed by CEPII is directly based on UN Comtrade data; it reconciles exporter and importer declarations and defines products at the 6-digit level from the Harmonized System (HS) nomenclature.

The price index is calculated using price data from the major extractive commodities[15] extracted from the World Bank's Pink Sheet; commodity trade data from Thibault Fally's dataset[16], and GDP data from the World Development Indicators. The real exchange index (REER), governance effectiveness index, and GDP per capita data were obtained from the World Development Indicators database.

The commodity dependence binary variables were built upon the corresponding categorization in UNCTAD (2019).

Table 1: Summary Statistics

	N	**Av.**	**SD**	**Min**	**Max**
Related variety (E_i)	2,958,320	0.02	0.02	-0.06	0.16
RCA	2,958,320	0.19	0.39	0.00	1.00
Non-extractives RCA	2,910,735	0.19	0.39	0.00	1.00
Extractives RCA	47,585	0.23	0.42	0.00	1.00

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[14] Table 5 in Annex reports the marginal effects of the LPM and CRE probit model in Equation (1) where different fixed effects are used: first, year, country and product effects, and then, product-time and country-time effects (as done in Klinger, (2006) in an LPM setting). In Table 6 and Table 7 the results for all coefficients/marginal effects are presented for Equation (1) and (2) using LPM and CRE probit model also using fixed effects. Results are comparable and remain robust through all specifications. Yet LPM coefficient values tend to be higher.

[15] This includes the following commodities and their corresponding HS4 codes: coal (2701), crude oil (2709), gas (2711); Aluminum(2606); Copper (2603); Iron ore (2601); Lead (2601); Nickel (2604); Tin(2609); Zinc (2608); Gold (7108); Silver (7106); and Platinum (7110).

[16] Thibault Fally's database also relies on the BACI database; yet it uses the HS-1992 nomenclature in order to cover a longer period, i.e. from 1995 to 2014 (Fally & Sayre, 2018).

Country-specific Mining Price Index (log)	2,676,055	0.11	0.25	0.00	1.48
REER Index (log)	1,699,518	4.58	0.14	4.03	5.73
Mining Commodity Dependence	2,676,055	0.10	0.30	0.00	1.00
Energy Commodity Dependence	2,676,055	0.14	0.35	0.00	1.00
Log GDP p.c. (Constant 2010 US$)	2,676,055	9.01	1.41	5.26	11.64
Log of Investment % of GDP	2,568,498	2.71	0.35	0.48	4.69

Table 1 summarizes the data employed in the analysis. Values in Table 1 for related variety (E_i) show that on average products have a value of 0.02, with a standard variation of 0.02 ranging from -0.06 to a maximum of 0.16. About 20% of products (in general and for the non-extractive category) were exported with a comparative advantage (i.e., an RCA equal or above to 1). In the case of extractive products, this is slightly higher, as 23% of exports showed comparative advantage.

4. Results

The estimates of equation (1) and its analogous probit specification are presented in Table 2 in Models (1) to (3). Results indicate that having comparative advantage ($RCA_{i,c,t}$) at the beginning of a period is a strong predictor of having comparative advantage four years later – regardless of the type of product. The estimate on the $RCA_{i,c,t}$ variable is positive and significant at the 1% level. The estimates indicate that having a comparative advantage in a given product at the beginning of a period increases the probability of having it four years later by 28.5 percentage points in the case of all products (Model 1), by 28.4 percentage points in non-extractive products (Model 2); and by 34.0 in extractive products (Model 3). These results remain robust throughout the different specifications presented in Table 2.

Similarly, results show that the related variety probability estimate, $E_{i,c,t}$, is positive and highly significant. Results in Table 2 suggest that an increase of a standard deviation (0.02) in the related variety estimate increases the probability of (all products') diversification four years later by 6.3 percentage points, (i.e., 3.16*0.02*100) (Model 1); in non-extractive products by 6.3 percentage points (Model 2); and, in extractive products by 7.0 percentage points (Model 3).

The estimates of equation (2) are presented in models 4 to 6 in Table 2. We also find that the effect of related variety is positive and highly significant (i.e. at the 1% level); yet the estimated coefficients reveal that its effect on maintaining comparative advantage, $(RCA_{i,c,t})^{*}\ E_{i,c,t}$, is higher than on developing new products, $(1\text{-}RCA_{i,c})^{*}\ E_{i,c,t.}$ Specifically, an increase of 0.02 (a standard deviation) in the related variety estimate, raises the probability of gaining comparative advantage in a new product (all products category) four years later by 5.8 percentage points, (Model 4); in new non-extractive products by 5.7 (Model 5); and in new extractive commodities by 8.0 percentage points (Model 6)

The above then highlights that path dependence may play a bigger role in extractives' diversification than in non-extractives – probably because, on average, the latter requires a more complex and/or diverse set of capabilities.

Furthermore, an increment of 0.02 (a standard deviation) in the related variety estimate increases the predicted probability of maintaining comparative advantage in products (all products category) four years later by 7.2 percentage points (Model 4); and in non-extractive products by 7.2 (Model 5). For extractives, this change would be equivalent to an increment of 6.0 percentage points (Model 6). This suggests that for extractive commodities, path dependence has a stronger effect on 'developing' new (extractive) products vis-à-vis non-extractive products, but it also has a weaker effect on preventing abandonment[17].

Table 2. Results – Basic Estimation

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	All products $RCA_{i,c,t+4}$	Non-extractive $RCA_{i,c,t+4}$	Extractive $RCA_{i,c,t+4}$	All products $RCA_{i,c,t+4}$	Non-extractive $RCA_{i,c,t+4}$	Extractive $RCA_{i,c,t+4}$
$RCA_{i,c,t}$	0.285***	0.284***	0.340***	0.268***	0.266***	0.353***
	(0.00436)	(0.00439)	(0.00691)	(0.00568)	(0.00577)	(0.00765)
Related variety, $E_{i,c,t}$	3.163***	3.138***	3.512***			
	(0.186)	(0.187)	(0.300)			
(1- $RCA_{i,c,t}$)* $E_{i,c,t}$				2.915***	2.869***	3.975***
				(0.212)	(0.213)	(0.334)
($RCA_{i,c,t}$)* $E_{i,c,t}$				3.612***	3.606***	3.026***
				(0.229)	(0.231)	(0.350)
Observations	2,958,320	2,910,735	47,585	2,958,320	2,910,735	47,585
Country Clusters	228	228	228	228	228	228

*** $p<0.01$, ** $p<0.05$, * $p<0.1$. Note: Country-clustered standard errors are shown in parenthesis. All models refer to the CRE probit estimation; coefficients refer to average marginal effects.

Models 4 to 6 in Table 3 show the results of equation (3) where macroeconomic controls, i.e., the log of the mining price index, the log of the real exchange rate, and log of GDP per capita, are incorporated. The related variety effect on diversification, $E_{i,c,t,}$ in models 1, 3, and 5 in Table 3 remains positive and significant at the 1% level. However, the size of the effect is now smaller: a standard deviation increase (0.02) in related variety is associated with an increase in the probability of diversification of 5.1 percentage points (Model 1), in non-extractive products by 5.0 percentage points (Model 3); and in extractive commodities by 5.2 percentage points (Model 5).

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[17] To test whether related variety coefficients are statistically different for non-extractive products than for extractive products, we carried out additional regressions in a pooled sample using the LPM approach in which the terms *Related variety,* $E_{i,c,t,}$ *,* *(1-* $RCA_{i,c,t}$*)** $E_{i,c,t}$ and *(*$RCA_{i,c,t}$*)** $E_{i,c,t}$ *,* are included, plus their respective interactions with a dummy variable that captures whether if the product is either a mineral, metal, or energy commodity. The results are shown in Table 8 in Annex.

Similarly, the effect of related variety on introducing a new product and maintaining comparative advantage remains positive and highly significant but the effects have reduced regardless of the type of product, as seen in Models 2, 4, and 6. A standard deviation increase (0.02) in related variety, is associated with an increase in the probability of diversification four years later of 4.8 percentage points in non-extractives products (Model 4) and 7.0 percentage points in extractive products (Model 6). Yet related variety has a stronger role in preventing abandonment in non-extractives than in extractives – as earlier observed. The above further underlines that developing comparative advantage in new non-extractive goods is less path-dependent than in mining and energy commodities; in other words, diversifying into non-mining or energy products requires bigger efforts or countries specialized in extractive sectors.

Regarding macroeconomic variables, we find some important differences as well. The mining price index coefficient reveals that an increase equivalent to a standard deviation (0.25) in the log of the price index is associated with a reduced probability of having comparative advantage in non-extractive products four years later equivalent to 12 percentage points (i.e., 0.48*0.25*100), significant at the 1% level (Model 3 and 4). A rather similar effect is found for all products (Model 1 and 2), also significant at the 1% level. Yet, there is no significant effect found for extractive products.

Moreover, the level of economic development shows a negative association with diversification overall. Models 1 to 4 suggest that an increase of 1.4 (a standard deviation in the sample) in the log of GDP per capita is associated with a reduction in the probability of diversification for all products and non-extractives equivalent to 4.2 percentage points (i.e., 0.03*1.4*100), results significant at the 5% and 10% levels respectively. This is in line with economic theory that states that export diversification increases at low levels of development but contracts at higher levels (Hesse, 2008; Klinger & Lederman, 2006).

The negative relationship however appears to be much larger and robust with extractive products. Models 5 and 6 in Table 3 indicate that an increment of 1.4 in the log of GDP per capita is associated with a reduction in the probability of having comparative advantage in extractive commodities equivalent to 13.3 to 13.6 percentage points, significant at the 1% level. This highlights that the more developed countries are, the less likely they will be to specialize in these goods.

The real exchange rate (REER) does not appear to be significant at any level across these specifications. This is consistent with the previous empirical works that failed to find a relationship between diversification and exchange rates. A possible explanation could be the vast number of currency management regimes and the circular causal relationship which was discussed in the literature review.

Finally, the introduction of controls did not have a noticeable effect on the marginal effects for the initial comparative advantage variable, $RCA_{i,c,t}$ – unlike the related variety marginal effects which became smaller. For this, the introduction of relevant macroeconomic variables linked to the macroeconomic environment is crucial to have a clearer picture of diversification determinants beyond path dependency. Moreover, results in Table 3 show that if the magnitude of the coefficients is compared – based solely on the variation (standard deviation) across countries, macroeconomic factors may play an equal, or stronger, role in explaining different diversification outcomes.

Table 3. Results - Estimation with macroeconomic controls

VARIABLES	(1) All products $RCA_{i,c,t+4}$	(2) All products $RCA_{i,c,t+4}$	(3) Non-extractive $RCA_{i,c,t+4}$	(4) Non-extractive $RCA_{i,c,t+4}$	(5) Extractive $RCA_{i,c,t+4}$	(6) Extractive $RCA_{i,c,t+4}$
$RCA_{i,c,t}$	0.295***	0.290***	0.294***	0.290***	0.336***	0.356***
	(0.005)	(0.007)	(0.005)	(0.007)	(0.009)	(0.011)
Related variety, $E_{i,c,t}$	2.537***		2.514***		2.600***	
	(0.200)		(0.200)		(0.348)	
$(1- RCA_{i,c,t})^* E_{i,c,t}$		2.627***		2.403***		3.475***
		(0.234)		(0.224)		(0.387)
$(RCA_{i,c,t})^* E_{i,c,t}$		2.726***		2.567***		2.099***
		(0.238)		(0.226)		(0.407)
Price Index (log)	-0.470***	-0.472***	-0.479***	-0.478***	-0.198	-0.213
GDP per capita (log)	-0.030**	-0.029**	-0.029*	-0.028*	-0.095***	-0.097***
	(0.015)	(0.014)	(0.015)	(0.015)	(0.022)	(0.022)
REER Index (log)	0.018	0.019	0.018	0.018	-0.011	-0.012
	(0.014)	(0.014)	(0.014)	(0.014)	(0.019)	(0.019)
Observations	1,699,518	1,699,518	1,671,028	1,671,028	28,490	28,490
Country Clusters	92	92	92	92	92	92

*** $p<0.01$, ** $p<0.05$, * $p<0.1$. Note: Country-clustered standard errors are shown in parenthesis. All models refer to the CRE probit estimation with product, country, and year effects; coefficients refer to average marginal effects.

Models in Table 4 incorporate further controls: i.e., mining and energy commodity dependence dummies, and the log of investment as a share of GDP. Results in Table 4 indicate that the related variety effect on having comparative advantage – regardless of the type of products – remains significant at the 1% level. The size of the marginal effect, however, decreases slightly. However, it must be said that in the specifications where the variable for investment is introduced the marginal effects increase again slightly. To illustrate this, a one standard deviation (0.02) increase in related variety would be associated with an increment of diversification in a new product four years later equivalent to 3.5 percentage points (Model 7), and if investment is controlled for, 4.4 percentage points (Model 8). Likewise, the equivalent increase in the probability of diversification in extractives would be 4.5 percentage points (Model 11), and if investment is controlled for, 4.9 percentage points (Model 12) (although, investment is not significant in the extractive diversification models). In any case, path dependence in new product diversification appears again to be higher for extractives than for non-extractives, as earlier noted.

Furthermore, mining commodity dependence is negatively associated with having comparative advantage in the category of all products and non-extractives. Specifically, having mining dependency is associated with a reduction in the predicted probability of diversification in all products equivalent to 1.3 percentage points (Models 1 and 3) and non-extractive products, equivalent to 1.0-1.5 percentage points (Models 5 to 8) significant at the 10% and 5% level (depending on the specification). Controlling for investment, however, seems to attenuate the effect as can be seen throughout Models 1 to 9; whenever this variable is introduced the effect of mining dependency seems to lose significance (or is significant at a lower significance level), with the marginal effect further shrinking. Results in Table 4 also show that mining commodity dependence and diversification in extractive commodities have a positive and highly significant relationship. Namely, mining dependence is associated with an increment in the probability of having comparative advantage in extractives equivalent to 4.9-5.3 percentage points (Models 9 to 12), significant at the 1% level.

Similarly, energy dependency shows the same pattern although the effect appears somewhat less robust than for mining: being dependent on fossil fuels and other energy products is associated with a decrease in diversification in new products (either in the all products or non-extractive products category) of between 1.3 and 1.4 percentage points, significant at the 10% and 5% level. In the specifications where the investment control is introduced, the negative effect loses significance. Likewise, results in Models 9 to 12 suggest that energy dependence is associated with an increment in the probability of diversification between 1.8 and 2.0 percentage points, significant at the 10% significance level. Recent divergence in the diversification trajectories of different oil countries and the overall trend towards higher mining dependence (UNCTAD, 2019) could explain why in recent years the effect of certain dependence could be now stronger for mining.

The effect of mining prices on non-extractive diversification – while smaller – remains negative and significant, even after controlling for commodity dependence and investment. To illustrate this effect, an increase of a standard deviation (0.25) in the log of the price index is associated with a reduced probability of having comparative advantage in non-extractive products four years later equivalent to 1.0-1.3 percentage points (Models 5 to 8), effects significant at the 1% level. Similar effects and significance are found for the specification in which all products are considered. Prices remain insignificant in the specifications for extractive products' diversification.

Once controls for commodity dependence and investment are introduced, the negative relationship between GDP per capita and diversification remains negative but appears less strong. Specifically, results indicate that a one standard deviation increment (1.4) in the log of GDP per capita is associated with a reduction in the probability of diversification for all products and non-extractives of between 1.3 and 1.7 percentage points (Models 1 to 8), significant at the 1% level. The effect for extractives however is equivalent to 2.2-2.3 percentage points (Models 9 to 12), also significant at the 1% level. The results again highlight that in advanced countries diversification becomes increasingly difficult to attain but also that these countries are less likely to move into extractive commodities – as earlier mentioned.

Table 4. Results - Estimation with macroeconomic controls, commodity dependence dummies, and investment (CRE Probit)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	All products RCA $_{i,c,t+4}$	All products RCA $_{i,c,t+4}$	All products RCA $_{i,c,t+4}$	All products RCA $_{i,c,t+4}$	Non-extractive RCA $_{i,c,t+4}$	Non-extractive RCA $_{i,c,t+4}$	Non-extractive RCA $_{i,c,t+4}$	Non-extractive RCA $_{i,c,t+4}$	Extractive RCA $_{i,c,t+4}$	Extractive RCA $_{i,c,t+4}$	Extractive RCA $_{i,c,t+4}$	Extractive RCA $_{i,c,t+4}$
RCA$_{i,c,t}$	0.295***	0.293***	0.281***	0.284***	0.294***	0.292***	0.279***	0.282***	0.358***	0.353***	0.369***	0.366***
	(0.003)	(0.003)	(0.004)	(0.005)	(0.003)	(0.003)	(0.004)	(0.005)	(0.007)	(0.006)	(0.007)	(0.007)
Related variety, E$_{i,c,t}$	2.097***	2.211***			2.088***	2.203***			1.708***	1.814***		
	(0.113)	(0.114)			(0.113)	(0.114)			(0.296)	(0.296)		
(1- RCA$_{i,c,t}$)* E$_{i,c,t}$			1.784***	2.065***			1.754***	2.039***			2.269***	2.450***
			(0.185)	(0.176)			(0.185)	(0.176)			(0.386)	(0.387)
(RCA$_{i,c,t}$)* E$_{i,c,t}$			2.386***	2.402***			2.394***	2.409***			1.321***	1.378***
			(0.126)	(0.133)			(0.127)	(0.133)			(0.308)	(0.307)
Price Index (log)	-0.050***	-0.042***	-0.051***	-0.041***	-0.052***	-0.043***	-0.053***	-0.043***	0.009	0.010	0.009	0.011
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.014)	(0.015)	(0.014)	(0.015)
GDP per capita (log)	-0.010***	-0.012***	-0.010***	-0.012***	-0.009***	-0.011***	-0.010***	-0.012***	-0.016***	-0.015***	-0.016***	-0.015***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)	(0.003)	(0.004)
Mining dependence	-0.013**	-0.009	-0.013**	-0.009	-0.014**	-0.010*	-0.015**	-0.011*	0.049***	0.053***	0.049***	0.053***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.015)	(0.015)	(0.015)	(0.015)
Energy dependence	-0.013*	-0.010	-0.013**	-0.010	-0.013*	-0.010	-0.014*	-0.011	0.018	0.020*	0.018*	0.020*
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)	(0.011)	(0.011)	(0.011)	(0.011)
Investment % of GDP (log)		0.013**		0.013**		0.013**		0.013**		-0.005		-0.006
		(0.006)		(0.006)		(0.006)		(0.006)		(0.013)		(0.014)
Observations	2,676,055	2,568,498	2,676,055	2,568,498	2,632,720	2,526,537	2,632,720	2,526,537	43,335	41,961	43,335	41,961
Country Clusters	178	165	178	165	178	165	178	165	178	165	178	165

*** $p<0.01$, ** $p<0.05$, * $p<0.1$. Note: Country-clustered standard errors are shown in parenthesis. All models refer to the CRE probit estimation with product, and year effects; coefficients refer to average marginal effects.

Finally, investment is (expectedly) positively associated with diversification in the all-products and non-extractive products models. Specifically, an increase of one standard deviation (0.35) in the log of the share of investment as GDP is associated with an increment in the probability of diversification equivalent to 0.455 percentage points, significant at the 1% level (Models 6 and 9). Results fail to find the same effect for extractive products suggesting that, on average, countries with higher levels of investment are less likely to develop towards extractive commodity sectors (perhaps deliberately) – akin to the dynamic observed for more advanced economies.

Estimations based on Table 4 (i.e., Models 3-4, 7-8, and 11-12) were also carried out with additional macroeconomic controls, i.e., log of inflation (from World Development Indicators), and a proxy to account for the quality of institutions, i.e., government effectiveness index (World Governance Indicators). These, however, were not significant in any of the models. Also, to test whether the relationship between product diversification and economic development, i.e., log of GDP per capita, follows a non-linear function, its squared term was introduced in the estimation of models reported in Table 4. The significance of this coefficient was not remarkably high (10%), yet the coefficients indicate a potential nonlinear relationship between GDP per capita and diversification. Namely, this relationship suggests – as highlighted in previous studies (i.e., Hesse, 2008; Klinger & Lederman, 2006) – that, at lower levels of development, export diversification increases but after a certain high-income point it begins to decline. Including these controls did not change much the significance and/or size of the estimated coefficients reported. Results of the above estimations are found in Annex (See Table 9).

4.1 Discussion of Results

A few observations can summarize our results: The related variety measure we use in our analysis (Nomaler & Verspagen, 2022) is a strong predictor of diversification. Our results confirm that path dependence, proxied by this measure, does play a role in predicting what countries produce with comparative advantage and what they do not. Specifically, our results show that this measure plays a weaker role in developing comparative advantage in non-extractive products vis-à-vis extractive products. This suggests that, indeed, diversifying in non-extractives requires somewhat "bigger jumps" due to more diverse and (probably complex) productive capabilities requirements.

However, related variety on its own does not reveal much about the underlying determinants and macroeconomic incentives facilitating (or hampering) diversification efforts. Results in the previous section show that the effect of related variety is affected by the inclusion of macroeconomic variables (e.g., international prices and investment) and it also impacts diversification across sectors differently (in this case, extractive sectors vs other sectors). Likewise, the magnitude of the marginal effects (if the standard deviation in the sample is considered) shows that macroeconomic factors play a crucial role in explaining differences. Our results support the idea that while path dependence is a good predictor, it is not deterministic. Diversification seems to hinge upon a whole range of macroeconomic factors that ultimately shape the incentives which lead to differences in diversification patterns. In this study, a few are identified and discussed.

Firstly, extractive commodity prices (captured by the country-specific mining index) show a consistent negative association with product diversification in non-extractive products. If extractive commodity dependence and investment are controlled for, the effect of commodity prices on diversification – although smaller – remains negative and significant. This is consistent with previous studies which have highlighted the negative relationship between commodity price shocks and export diversification (i.e., Agosin et al., 2012). Results however also show that mining price indices, however, do not incentivize diversification into other non-extractives. Higher prices, thus, may incentivize extracting more of a commodity but are not necessarily conducive to new extractive sectors probably because of the exogenous nature of these resources (i.e., a country either has lithium or not). Additionally, higher prices may not be sufficient to offset the high barriers and requirements involved in developing a new extractive sector.

Likewise, energy- and mining-dependent countries (especially the latter) are less likely to diversify into non-extractive commodity products. Since the effect seems to be particularly strong for mining products, this finding partially contradicts previous studies that indicate that only oil hampers diversification (e.g., Ahmadov, 2014). Possibly this is because while the export concentration in energy-dependent countries remains high, there have been a few mixed experiences more recently[18].

Yet in this regard, results suggest that investment can attenuate commodity dependence effects on diversification as investment is positively associated with diversification in non-extractive sectors (and not with extractive commodities). This finding supports the view that diversification is an endogenous process stemming from investments (e.g., Acemoglu and Zilibotti, 1997) as well as previous empirical works (e.g. Esanov, 2012).

Results do not show that the real exchange rate index is statistically associated with diversification (or the lack thereof). The lack of a clear empirical relationship of currency movements with diversification could be attributed not only to the potential bi-directional causality between the variables but also because of the current diversity in exchange rate regimes.

We further confirm – once commodity dependence is controlled for – that at lower levels of development – proxied by GDP per capita – there is more room for diversification, regardless of the type of product considered. However, results also suggest that the more developed a country is, the less likely it will be to diversify into (mining and energy) commodities.

Finally, our results remain robust across estimations in which other controls, such as inflation, and governance effectiveness, are included.

5. Conclusion

The analysis here presented shows that non-extractive diversification is less path-dependent than extractives, and thus requires stronger efforts to attain. If countries want to diversify their export portfolio this may require taking more than a few small steps to achieve that goal and so, the entrepreneurial cost of discovery in non-extractive sectors will be higher.

Furthermore, these results confirm that macroeconomic incentives, namely those provided by international prices, are crucial in establishing the direction of diversification; in this case, results suggest that higher commodity prices tend to push countries away from non-extractive exports.

The exact way in which prices lower the probability of diversification into non-extractives is less clear. It is possible that in some countries this channel is the real exchange rate (as the Dutch disease would suggest). Yet

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[18] Energy dependent countries, such as Oman, Trinidad and Tobago, and Qatar became more diversified in the 1995-2017 period; yet others such as Azerbaijan, Venezuela and Nigeria became even more concentration (UNCTAD, 2019).

this study could not confirm that on average this is the main way in which it operates. Agosin et al. (2012) give another possible explanation: higher commodity prices will incentivize the allocation of factors into the extractive sector which will increase the costs of inputs and/or reduce their availability necessary for producing other goods competitively.

Considering that it is likely that the demand for minerals and metals will remain high, or even increase, it should be considered that diversifying into new non-extractives may be harder because incentives make the relative cost of inputs (and overall innovative activity) higher. Further research into how macroeconomic conditions reduce incentives of entrepreneurs to move into new non-extractive products would be necessary. Another possible research agenda would be to look at how the institutional setup in a more disaggregated manner (for instance, by looking at political economy aspects) facilitates or discourages non-extractive diversification.

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Annex

Annex 1: Additional regressions

Table 5. Comparison of Marginal Effects for Related Variety based on Equation (1)

	(1)	(2)	(3)	(4)
	LPM	CRE Probit	LPM	CRE Probit
	All products RCA $_{i,c,t+4}$	All products RCA $_{i,c,t+4}$	All products RCA $_{i,c,t+4}$	All products RCA $_{i,c,t+4}$
Related variety, $E_{i,c,t}$	4.913***	3.163***	6.859***	4.539***
	(0.301)	(0.186)	(0.391)	(0.0478)
Year	Yes	Yes	-	-
Country	Yes	Yes	-	-
Product	Yes	Yes	-	-
Country*Year	-	-	Yes	Yes
Product*Year	-	-	Yes	Yes
N	2,958,319	2,958,320	2,957,792	2,958,320

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Models 2 and 4 report average marginal effects. Country-clustered SEs are shown in parenthesis.

Table 6. Results – Equation 1: CRE Probit and LPM with Fixed Effects

	(1)	(2)	(3)	(4)	(5)	(6)
	LMP	*CRE Probit*	*LMP*	*CRE Probit*	*LMP*	*CRE Probit*
VARIABLES	All products RCA $_{i,c,t+4}$	All products RCA $_{i,c,t+4}$	Non-extractive RCA $_{i,c,t+4}$	Non-extractive RCA $_{i,c,t+4}$	Extractive RCA $_{i,c,t+4}$	Extractive RCA $_{i,c,t+4}$
RCA$_{i,c,t}$	0.540***	0.285***	0.539***	0.284***	0.553***	0.340***
	(0.0108)	(0.00436)	(0.0109)	(0.00439)	(0.0110)	(0.00691)
Related variety, $E_{i,c,t}$	4.913***	3.163***	4.911***	3.138***	3.656***	3.512***
	(0.301)	(0.186)	(0.303)	(0.187)	(0.360)	(0.300)
Observations	2,958,319	2,958,320	2,910,734	2,910,735	47,585	47,585
Adj./Pseudo R-squared	0.411	0.344	0.411	0.345	0.396	0.315
Country Clusters	228	228	228	228	228	228

*** $p<0.01$, ** $p<0.05$, * $p<0.1$. Note: Country-clustered SEs are shown in parenthesis. Coefficients are reported for LMP with fixed effects and average marginal effects reported for CRE Probit. All models include year, product and country effects

Table 7. Results – Equation 2: CRE Probit and LPM with Fixed Effects

	(1)	(2)	(3)	(4)	(5)	(6)
	LMP FE	CRE Probit	LMP FE	CRE Probit	LMP FE	CRE Probit
VARIABLES	All products RCA $_{i,c,t+4}$	All products RCA $_{i,c,t+4}$	Non-extractive RCA $_{i,c,t+4}$	Non-extractive RCA $_{i,c,t+4}$	Extractive RCA $_{i,c,t+4}$	Extractive RCA $_{i,c,t+4}$
$RCA_{i,c,t}$	0.494***	0.268***	0.491***	0.266***	0.563***	0.353***
	(0.0119)	(0.00568)	(0.0121)	(0.00577)	(0.0126)	(0.00765)
$(1- RCA_{i,c,t})* E_{i,c,t}$	3.643***	2.915***	3.578***	2.869***	4.027***	3.975***
	(0.301)	(0.212)	(0.302)	(0.213)	(0.395)	(0.334)
$(RCA_{i,c,t})* E_{i,c,t}$	5.680***	3.612***	5.702***	3.606***	3.286***	3.026***
	(0.362)	(0.229)	(0.367)	(0.231)	(0.461)	(0.350)
Observations	2,958,319	2,958,320	2,910,734	2,910,735	47,585	47,585
Adj./Pseudo R-squared	0.412	0.3461	0.412	0.3468	0.396	0.3170
Country Clusters	228	228	228	228	228	228

*** p<0.01, ** p<0.05, * p<0.1. Note: Country-clustered SEs are shown in parenthesis. Coefficients are reported for LMP with fixed effects and average marginal effects reported for CRE Probit. All models include year, product and country effects

Table 8. Statistical difference between commodities and non-commodity products

	(1)	(2)
	LPM	LMP
	All products RCA $_{i,c,t+4}$	All products RCA $_{i,c,t+4}$
$RCA_{i,c,t}$	0.539***	0.491***
	(0.011)	(0.012)
$RCA_{i,c,t}$ * Extractive Commodity Dummy	0.044***	0.107***
	(0.011)	(0.012)
$(1- RCA_{i,c})* E_{i,c}$		3.620***
		(0.300)
$(RCA_{i,c})* E_{i,c}$		5.727***
		(0.367)
$(1- RCA_{i,c})* E_{i,c}$ * Extractive Commodity Dummy		-0.564*
		(0.294)
$(RCA_{i,c})* E_{i,}$ * Extractive Commodity Dummy		-3.421***
		(0.442)
$E_{i,c,t}$	4.929***	
	(0.302)	
$E_{i,c,t}$ * Extractive Commodity Dummy	-1.838***	
	(0.304)	
Constant	0.022***	0.038***
	(0.003)	(0.004)
N	2,958,319	2,958,319
R-squared	0.412	0.413
Country Clusters	228	228

*** p<0.01, ** p<0.05, * p<0.1. Note: Country-clustered SEs are shown in parenthesis. All models include product, country, and year-specific fixed effects.

Table 9 . More controls based on Table 4: Governance effectiveness, inflation and log of GDP per capita^2 (CRE probit)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All products RCA $_{i,c,t+4}$	All products RCA $_{i,c,t+4}$	All products RCA $_{i,c,t+4}$	Non-extractive RCA $_{i,c,t+4}$	Non-extractive RCA $_{i,c,t+4}$	Non-extractive RCA$_{i,c,t+4}$	Extractive RCA $_{i,c,t+4}$	Extractive RCA $_{i,c,t+4}$	Extractive RCA $_{i,c,t+4}$
RCA$_{i,c,t}$	0.284***	0.285***	0.286***	0.282***	0.283***	0.284***	0.366***	0.368***	0.367***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)	(0.007)	(0.007)
(1-RCA)* E$_{i,c,t}$	2.081***	2.050***	2.093***	2.055***	2.024***	2.065***	2.446***	2.399***	2.522***
	(0.175)	(0.179)	(0.179)	(0.174)	(0.179)	(0.179)	(0.386)	(0.378)	(0.393)
(RCA)* E$_{i,c,t}$	2.413***	2.376***	2.384***	2.420***	2.384***	2.392***	1.376***	1.292***	1.334***
	(0.133)	(0.135)	(0.134)	(0.134)	(0.135)	(0.135)	(0.302)	(0.304)	(0.302)
Price Index (log)	-0.039***	-0.041***	-0.040***	-0.041***	-0.043***	-0.042***	0.013	0.011	0.011
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.016)	(0.016)	(0.015)
GDP per capita (log)	-0.014***	-0.039**	-0.012***	-0.014***	-0.038**	-0.012***	-0.017**	-0.095***	-0.015***
	(0.003)	(0.015)	(0.002)	(0.003)	(0.015)	(0.002)	(0.007)	(0.032)	(0.004)
Mining dependence	-0.009	-0.012*	-0.011*	-0.011*	-0.014**	-0.013**	0.052***	0.044***	0.052***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.015)	(0.015)	(0.016)
Energy dependence	-0.009	-0.010	-0.011	-0.009	-0.011	-0.011	0.022*	0.021*	0.023*
	(0.008)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.012)	(0.012)	(0.012)
Governance effectiveness	0.003			0.003			0.004		
	(0.004)			(0.004)			(0.008)		
Investment % of GDP(log)	0.013**	0.013**	0.012**	0.013**	0.014**	0.012**	-0.005	-0.004	-0.009
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.014)	(0.013)	(0.015)
GDP per capita^2 (log)		0.002*			0.001*			0.005**	
		(0.001)			(0.001)			(0.002)	
Inflation (log)			-0.003			-0.003			-0.007
			(0.004)			(0.004)			(0.008)
Observations	2565851	2568498	2478424	2523911	2526537	2437826	41940	41961	40598

*** $p<0.01$, ** $p<0.05$, * $p<0.10$. Note: Country-clustered SEs are shown in parenthesis. Coefficients reported refer to marginal effects. All models include controls for product and year-specific effects.

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