An Empirical Study of the Relationship between Exchange Rate Misalignments, Economic Complexity and Export Diversification

Neil Foster-McGregor and Danilo Spinola

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Abstract

This study examines the influence of real exchange rate (RER) misalignments on economic complexity and export diversification across a range of countries, utilising a panel vector autoregression (VAR) methodology. Our research extends to an extensive panel (1962 to 2019) encompassing 151 countries. We employ the metric devised by Rodrik (2008) concerning RER misalignment – adjusted for the Balassa-Samuelson effect – and correlate this measure with export diversification, drawing upon the literature centred on the product space tradition (Hausmann and Hidalgo, 2014). Contrary to prevailing assumptions that RER misalignments universally enhance exports and economic complexity, our findings reveal a nuanced and varied relationship. The analysis indicates that RER deviations can profoundly affect the structure of national economies, directing export diversification in unforeseen ways and not consistently leading to increased complexity. Furthermore, the effects of RER misalignments are enduring, with the potential to spur long-term technological advancement and the development of advanced production capacities. Recognising the intricate dynamics of the global economic system, this paper contributes to the discussion on exchange rate policies and economic development, proposing future research to further explore this complex relationship. It seeks to provide valuable insights for policymakers and academics on the subtle effects of exchange rate dynamics on economic growth strategies.

Keywords: RER misalignment, economic complexity, Balassa-Samuelson effect

JEL Codes: O11, O57, F31

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1. Introduction

There currently is an escalating debate about the role of exchange rate dynamics in influencing domestic production competitiveness. The undervalued exchange rate in nations that have recently enhanced the sophistication of their production frameworks, such as China and South Korea, sparks discussions about the extent to which exchange rate discrepancies can serve as a tool to encourage diversification. In contrast, countries with overvalued currencies have observed a trend towards specialising their infrastructure to produce primary goods and natural resources.

There is a strand within the debate literature that champions the importance of employing the exchange rate as an active policy instrument to bolster the manufacturing and contemporary sectors (Guzman et al. 2018; Lavopa and Szirmai 2018; Rodrik 2008). Of late, factors such as commodity price rises, quantitative easing approaches and financialisation have influenced exchange rate dynamics in developing nations. Economies in Africa and Latin America with open capital accounts have endured a prolonged appreciation of their exchange rates, underpinned by substantial foreign currency influxes (Damill and Frenkel 2017; Diao and McMillan 2018; Diao et al. 2019). Scholars contend that this trend has notably affected the sectoral makeup and the level of technological intensity within these economies. Conversely, burgeoning Asian powerhouses like China and South Korea have effectively shielded themselves from their exchange rate appreciation. These nations deployed RER management as a strategic policy tool, aiming for extensive structural evolution towards contemporary sectors (Rapetti et al. 2012).

Considering the economic transition observed in recent decades, the interplay between exchange rate policies and domestic production strategies has never been more pertinent. Exchange rates influence trade balances and capital flows, and play a vital role in shaping a nation's competitive edge in global markets. In particular, the strategic alignment between a country's exchange rate policy and development goals becomes paramount when considering production diversification and industrialisation. The transformation witnessed in China and South Korea underscores the potential advantages of such strategic congruence. Here, a deliberate and calculated use of undervalued exchange rates complemented the nations' ambitious plans to ascend the global manufacturing ladder, fostering innovation and diversification.

Furthermore, the significance of exchange rates extends beyond immediate trade benefits. Its effects permeate deep into the core of a nation's production capacities, influencing technological upgradation, research and development decisions, and investment priorities. The trajectory of countries with overvalued currencies often veers towards harnessing their natural resources. In contrast, undervalued currencies can be a launchpad for venturing into more sophisticated, high-value industries. The strategic manipulation of exchange rates can thus be envisioned as a fiscal tool and a broader instrument of economic statecraft, propelling nations towards desired developmental milestones.

Building upon the foundation laid by Rodrik (2008), our research delves into the ramifications of currency misalignment for a country's economic structure. By assessing the degree of deviation from the benchmark exchange rate that would favourably bolster the manufacturing sector, we can quantitatively decipher the extent of a currency's overvaluation or undervaluation.

Also, our approach integrates the principles of the product space tradition, which offers a framework to study the dynamics of economic complexity (Hidalgo and Hausmann 2009). Specifically, we study the relationship between currency misalignment and the qualitative aspects of a country's productive matrix, given by the product space tradition. We examine the degree of export diversification through the lens of the economic complexity index (ECI), a nuanced metric that gauges product ubiquity and relatedness. Our study therefore stands at the confluence of macroeconomic policies and microeconomic structures, offering a holistic view of the multifaceted interplay between exchange rate dynamics and national productive capacities.

The structure of this paper is organised as follows: Following the introductory segment, Section 2 delves into a comprehensive literature review. Section 3 outlines the methodology employed in our analysis, while Section 4 is dedicated to the econometric approaches utilised. Section 5 presents the findings derived from our analysis. The paper concludes with Section 6, in which our main conclusions and insights are summarised.

2. Literature Review

2.1 Exchange Rate Misalignments

In the literature on exchange rate misalignments, many important works investigate how an undervalued real exchange rate boosts growth (Acemoglu et al. 2003; Easterly 2001; Glüzmann et al. 2012; Hausmann et al. 2005; Razin and Collins 1997; Vieira and MacDonald 2012). Most of these works focus on developed countries. This relationship, however, shows ever more vital dynamics for developing countries, in which the exchange rate is also more volatile (Gala 2018; Rapetti et al. 2012; Rodrik 2008). Looking at developing economies, Frenkel and Ros (2006) examined the role of the exchange rate in determining employment performance and its transmission through various channels. Their contribution highlights the existence of three channels:

1. **The macroeconomic channel**: devaluation leads to higher competitiveness, which increases exports, demand, output and employment.

2. **Labour intensity channel:** devaluations boost the profitability of tradable sectors and encourage more intensive labour use. That cuts off profitability, enabling firms to increase their competitiveness.
3. **Development channel:** devaluations are associated with export promotion industrialisation. RER establishes the relative prices of tradable and non-tradable goods. It acts as a tariff on imports and as a subsidy on exports. A competitive RER raises the tradable sector's profitability, pushing for higher production and promoting structural change.

On the basis of the third channel described above, Rodrik (2008) argues that devaluations boost the profitability of tradable sectors, especially manufacturing ones. He then offers two explanations for the causal link between exchange rate devaluation, profitability of tradable sectors and growth for developing countries. Rodrik's (2008) explanations are focused on bad institutions of low-income countries acting as a higher tax on tradable sectors – by increasing profitability, exchange rate devaluations increase investment and efficiency, and *undervaluation is a substitute for industrial policy*. The idea is that exchange rate policy remediates the market failures of tradable sectors. Economic development is a process of structural change towards a more diversified and complex structure, and market failures are more severe in new lines of production. Exchange rate devaluations then induce the production of new products and entail higher long-run growth.

Although the literature supports the view that the exchange rate affects long-run growth, some authors also indicate an indirect effect via structural change. The exchange rate is connected to the profitability of the tradable sectors and its investment and employment decisions. As devaluations distort the relative prices in favour of tradable sectors and decrease the real wage, higher profitability enhances production and investment, promoting the reallocation of resources to tradable sectors. Therefore, as the tradable sectors encompass the manufacturing sectors, devaluations of the exchange rate boost the long-run growth directly and indirectly via its effects on **profitability**, and then on the **structural composition** of the economy (Marconi et al. 2022; Razin and Collins 1997). That is the channel we would like to explore in this research.

2.2 Economic Complexity

The case for the role of diversification (particularly towards the industrial sector) in promoting sustainable growth and development at a national level is not a novel one. It has its roots in classical Structuralist debates (Jameson 1986). Nonetheless, it remains a pertinent and relevant subject, given that industry continues to be a pivotal driver of growth (Haraguchi 2015; Szirmai 2012). The latest scholarship on economic complexity adds to this discussion (Gala et al. 2018) by examining and ranking diversification trends through complexity metrics.

The debate on economic complexity recently gained momentum with the works of what we will call the *product space* school[1] (Hausmann and Hidalgo 2011). Their discussion seeks to connect export diversification with learning and technological evolution. As per the proponents of this school of thought, learning necessitates structural transformation, given that a novel industry calls for shifts in interactions within organisations and economic sectors (Hausmann and Hidalgo 2011).

In the *product space* complexity theory, there are two basic concepts used to measure whether a country is economically complex: (1) ubiquity and (2) diversity of the products in its export basket (Gala et al. 2018; Hidalgo and Hausmann 2011). The exports of non-ubiquitous (rare) goods indicate a more sophisticated structure.

Non-ubiquitous products are categorised into (a) items with high technological content, those that are challenging to produce, and (b) items that are naturally rare, like diamonds, thus being inherently non-ubiquitous. To account for naturally scarce products, Hidalgo and Hausmann (2011) contrast ubiquity with the diversity of exports from countries that also produce and export the same product, constructing an index to gauge the complexity of exports, namely the Economic Complexity Index (ECI) (See section 3.4).

Lastly, the discourse on export diversification connects to potential avenues for economic growth. Hausmann et al. (2007) states that diversifying exports can lead to heightened growth. Felipe et al. (2012) and Hartmann et al. (2017) show a positive correlation between a country's export complexity and its per capita income. Hidalgo and Hausmann (2009) contend that the complexity of export diversity can also be a predictive tool for future growth. Hausmann et al. (2007) identify a favourable relationship between a country's growth and the income of its product-importing nations. Employing Instrumental Variable (IV) estimations, causality flows from the destination of imports to the income of the exporter.

Gala et al. (2018) also contend that the primary merit of the ECI is its lack of qualitative concerns related to production and exports. There is no predefined notion of what is complex or non-complex; these distinctions emerge from linear algebra computations. Following this approach, the authors evaluate various countries, establishing solid correlations between per capita income levels, inequality, and economic complexity.

2.3 Criticisms of the Literature on RER Misalignments

The debate surrounding the impact of exchange rate misalignment on economic growth and export diversification presents a nuanced challenge to conventional economic theories. Sekkat (2016) critically examines the conditions under which exchange rate misalignment,

[1] We refer to this literature as product space theory, as complexity economics is a very broad area that links to the works of the Santa Fe institute. Product space theory consists of a very specific application of complex theory to compute export diversification.

encompassing overvaluation and undervaluation, would influence export diversification within the manufacturing sector. By analysing export diversification through the lenses of the Gini index, the Theil index, the Herfindahl index, and the ratio of total manufactured exports to total exports, Sekkat finds no empirical support for a significant influence of misalignment on diversification. This finding aligns with the observations of Agosin et al. (2012) and Levy-Yeyati et al. (2013), who also report difficulties establishing a definitive causal link between exchange rate misalignment and export diversification. Miao and Berg (2010) contribute to this discourse by highlighting the challenges of accurately measuring misalignment based on purchasing power parity (PPP), pointing out that such measurements may not truly reflect economic disequilibrium, thereby overlooking broader economic costs.

Ribeiro et al. (2016) states that the positive effects of real exchange rate (RER) devaluation on economic growth are contingent upon the economy being profit-led, where devaluations serve to enhance price competitiveness. This view introduces the critical role of institutional conditions in mediating the effects of RER misalignment on economic outcomes. Similarly, Rodrik (2008) stresses the significance of institutional quality, suggesting that the impact of misalignment may vary across countries due to differing institutional frameworks, even when making distinctions between developed and developing economies. This argument is further expanded by Aghion et al. (2009) and Elbadawi et al. (2012), who identify the level of financial development as another factor that can significantly influence the outcomes of exchange rate misalignment.

The literature furthermore also explores the ramifications of an undervalued currency on the cost of importing intermediary inputs and capital goods, which are vital for the production of sophisticated final goods. This discussion offers a counterpoint to narratives on institutional weaknesses, with studies by Svensson (2003) indicating that institutional elements, such as corruption, may inadvertently boost the number of exporters by facilitating market entry or reducing operational constraints.

Heckman (2008) addresses the perennial issue of distinguishing causality and correlation within this context. He critiques the methodological approach commonly adopted in empirical research, which often involves drawing connections between exchange rate behaviour and subsequent economic diversification. He argues that such associations, without robust methodological frameworks to rigorously test causality, are insufficient to conclusively attribute enhanced export diversification to currency undervaluation.

3. Methodology

3.1 Description of the Data

We incorporate an analysis of macroeconomic and product-level data to construct indices of economic complexity and metrics for measuring diversity. The source of the macroeconomic data is the Penn World Tables (PWT) and the World Development Indicators (WDI), providing a country-level economic overview. On the other hand, product-level insights are derived from the International Trade Database at the Product Level (BACI) and data from World Trade Flows (documented by Feenstra et al. 2005), focusing on the specifics of international trade.

The methodology employed is a panel data analysis, which examines the relationship between the dependent variables – complexity, exports and diversification – and the independent variables, specifically the exchange rate gap and volatility. This approach aims to understand how these economic indicators interact and influence each other over time.

The data characteristics are summarised in Table 1, which lists the variables and their sources, and provides brief explanations. For instance, the real exchange rate (RER) is calculated from the PWT for each country and year, indicating the price-level comparison between countries. Trade data from 1962 to 2019 was sourced from both BACI and World Trade Flows, offering detailed information on international trade dynamics at the SITC1 level. The complexity scores were generated from the Atlas of Economic Complexity for 151 countries, from 1962 to 2019, reflecting the economic complexity of countries based on their export profiles. Export values were derived from the World Development Indicators, covering 213 countries and providing data on total export values and the diversity of exported products.

Table 1. Data characteristics

Variable	Source	Explanation
Real exchange rate (RER)	Penn World Tables (PWT)	Data computed from the PWT for each country and year, as $xr = ppp/pl_{gdpo}$.
Trade data	BACI / World Trade Flows	SITC1 level for the period 1962 to 2019. (Feenstra's world trade flows data with data from BACI).
Complexity scores	Atlas economic complexity for 151 countries, 1962 to 2019	The country complexity score from HH is based on RCAs. It is computed as the weighted average of product complexity scores, where the weights are export shares (including all exports).
Export values	World Development Indicators, 213 countries	Total export values (and number of RCAs as a further measure of diversity).

A notable issue in the data collection process is the introduction of new product codes by Feenstra, designed to aggregate problematic product codes, and the significant data discrepancy observed when transitioning to BACI data for many countries. To address these challenges, the study employs averages to smooth over these breaks in the data between 1996 and 2000.

Table 2 details the variables used in the analysis, including log exports, complexity, diversity, log of undervaluation, trade, and government consumption. Each variable is labelled and described, such as the logged value of total exports, the complexity score, and the number of products exported with a revealed comparative advantage (RCA). The inclusion of additional explanatory variables is informed by previous research and the availability of data that spans a lengthy period and covers a wide range of countries.

Table 2: Variables

Variable	**Label**	**Description**
Log exports	*lnexp*	Logged value of total exports
Complexity	*comp_i*	Value of the complexity score (using the method of reflection)
Diversity	*lndiversity*	Number of products exported with RCA
Log Underval	*lnunderval*	Log of an index of exchange rate undervaluation, computed as by Rodrik (2008)
Trade	*trade_gdp*	The ratio of trade to GDP
Gov	*ggfc*	Share of general government final consumption expenditure in GDP

The set of additional explanatory variables is driven by existing studies (e.g., Issah and Antwi 2017) and data availability, with the need for variables with long time series for a broad range of countries.

3.2 Panel Var Methodology (taken from Canova and Ciccarelli 2013)

In vector autoregression (VAR) models, every variable is considered both influenced by and influencing other variables in the system. This mutual dependence is encapsulated in the formulation where Y_t, a vector representing multiple endogenous variables at a time t, is modelled to reflect its own past values, its interaction with other variables, and an error term. The equation for Y_t is given as:

$$Y_t = A_0(t) + A(l)Y_{t-1} + u_t \qquad (1)$$

$$u_t \sim iid(0, \Sigma_u), \qquad (2)$$

where u_t is an error term assumed to be independently and identically distributed, with a mean of zero and a variance of Σ_u. The term $A(l)$ represents a polynomial lag operator applied to the vector of endogenous variables that encapsulates the dynamics of their interactions across different time lags.

To ensure the model is both statistically stable and practically useful, certain restrictions are applied to the coefficients within A_j, such as ensuring that the system's responses over time do not explode in variance. This is typically achieved by enforcing conditions on the eigenvalues of the coefficient matrices, such as ensuring they do not lie on or within the unit circle in the complex plane.

The introduction of $A_0(t)$ aggregates the deterministic components of the model, simplifying the representation of external influences or predetermined trends within the data.

In some variants of VAR, especially those focusing on small open economies, the model is expanded to include exogenous variables (W_t), which influence but are not influenced by the system, resulting in the following form:

$$Y_t = A_0(t) + A(l)Y_{1,t-1} + F(l)W_{2t} + u_t. \quad (3)$$

Finite-order, fixed-coefficient VARs can be derived in many ways. The standard one is to use the Wold theorem and assume linearity, stationarity and invertibility of the resultant moving average representation. Under these assumptions, there is an (infinite lag) VAR representation for any vector, Y_t. To truncate this infinite-dimension VAR and use a VAR(p), p finite, in empirical analyses, we further need to assume that the contribution of Y_{t-j} to Y_t is small when j is large.

Panel VARs have the same structure as VAR models in the sense that all variables are assumed to be endogenous and interdependent. Still, a cross-sectional dimension is added to the representation. Thus, think of Y_t as the stacked version of y_{it}, the vector of G variables for each unit $i = 1, \dots, N$, i.e., $Y_t = (y'_{1t}, y'_{2t}, \dots, y'_{Nt})'$. The index i is generic and could indicate countries, sectors, markets or combinations of them. Then, a panel VAR is:

$$y_{it} = A_{0i} + A_i(l)Y_{t-1} + u_{it} \quad i = 1, \dots, N \; t = 1, \dots, T, \qquad (4)$$

where u_{it} is a $Gx1$ vector of random disturbances and, as the notation makes it clear, $A_{0i}(t)$ and A_i may depend on the unit.

When a panel VARX is considered, the representation is:

$$y_{it} = A_{oi}(t) + A_i(l)Y_{1t-1} + F_i(l)W_t + u_{it}, \; (5)$$

where $u_t = [u_{1t}, u_{2t}, \dots, u_{Nt}]' \sim iid(0, \Sigma)$, $F_{i,j}$ are GxM matrices for each lag $j = 1, \dots, q$, and W_t is an $Mx1$ vector of predetermined or exogenous variables, common to all units i.

Simple inspection of (2) or (3) suggests that a panel VAR has three characteristic features. First, lags of all endogenous variables of all units enter the model for unit i: we call this feature "dynamic interdependencies". Second, u_{it} are generally correlated across i: we call this feature "static interdependencies". In addition, since the same variables are present in each unit, there are restrictions on the covariance matrix of the shocks.

Third, the intercept, the slope and the variance of the shocks, u_{it}, may be unit specific: we call this feature "cross-sectional heterogeneity". In this case, interdependencies are typically disregarded and sectoral homogeneity (allowing for certain time-invariant individual characteristics) is typically assumed. It also distinguishes the setup from others used in the macroeconomic literature, where either cross-sectional homogeneity is assumed and/or dynamic interdependencies are *a priori* excluded. In a way, a panel VAR is similar to large-scale VARs in that dynamic and static interdependencies are allowed. It differs because cross-sectional heterogeneity imposes a structure on the covariance matrix of the error terms.

3.3 Real Exchange Rate Adjusted for the Balassa-Samuelson Effect Misalignments (Rodrick 2008)

The undervaluation index is constructed by adjusting the real exchange rate (RER) for the Balassa-Samuelson effect. This adjustment is crucial, as it accounts for the differential in price levels between tradable and non-tradable goods. As countries experience economic growth, the price of non-tradable goods, compared to tradable goods, tends to increase due to relatively higher productivity gains in the tradable sector. This phenomenon is particularly noted in the context of developing countries, where there is a discernible pattern linking currency undervaluation with economic growth. The direction of causality in this relationship strongly suggests that undervaluation fosters growth, rather than growth leading to undervaluation.

Data on exchange rates (XRAT) and purchasing power parity (PPP) conversion factors were sourced from the Penn World Tables (PWT) to calculate the adjusted real exchange rate. The formula used is:

$$lnRER_{it} = ln(XRAT_{it}/PPP_{it}), \qquad (6)$$

where i represents different countries and t denotes distinct five-year intervals. Both $XRAT$ and PPP are measured in terms of the national currency unit per US dollar. An RER value exceeding one suggests that the currency is more depreciated than what purchasing power parity would indicate. This discrepancy necessitates an adjustment for the Balassa-Samuelson effect, which is accomplished by regressing the RER against GDP per capita (RGDPCH):

$$lnRER_{it} = \alpha + \beta \ln RGDPCH_{it} + f_t + u_{it}. \quad (7)$$

Here, f_t represents time-specific fixed effects. The undervaluation index is then derived by calculating the difference between the observed real exchange rate and the rate adjusted for the Balassa-Samuelson effect, termed the exchange rate gap:

$$lnUNDERVAL_{it} = \ln RER_{it} - \ln \widehat{RER_{it}}. \qquad (8)$$

Whenever $UNDERVAL$ exceeds unity, the exchange rate is set such that goods produced at home are relatively cheap in dollar terms: the currency is undervalued. Utilising a dataset encompassing 188 countries across 11 five-year periods from 1950 to 1954 and 2000 to 2004, as compiled by Rodrik (2008), the baseline model for analysing the impact of undervaluation on growth is established as follows:

$$growth_{it} = \alpha + \beta \ln RGDPCH_{i,t-1} + \delta \ln UNDERVAL_{it} + f_i + f_t + u_{it}. \quad (9)$$

In this model, the dependent variable is the annual growth rate of GDP per capita, with $ln(RGDPCH_{i,t-1})$ serving as a proxy for initial income levels, facilitating the exploration of standard economic convergence theories. The inclusion of both country and time fixed effects (f_i and f_t, respectively) allows for a nuanced examination of the growth effects of currency undervaluation, accounting for unobserved heterogeneity both across countries and over time. This analytical framework offers a sophisticated tool for understanding the complex dynamics between currency valuation and economic development.

3.4 Economic Complexity Index

Based on Mealy et al. (2019) and Balland et al. (2022), the Economic Complexity Index (ECI) (Hidalgo and Hausmann 2009) and the Product Complexity Index (PCI) are sophisticated metrics developed using a specialised algorithm that interacts with a binary matrix, labelled M. This matrix establishes a relationship between countries (notated as c) and products (notated as p), creating a framework to analyse the economic complexity of nations and the complexity of individual products. Within this matrix, the specific element M_{cp} is allocated a value of 1 under the condition that a given country (c) either shows a level of competitiveness or holds a revealed comparative advantage (RCA) exceeding the threshold of 1 in relation to a particular product (p). This method of determination employs the Balassa index, a well-regarded economic formula designed to measure comparative advantage by comparing a country's performance in a specific product relative to its overall economic performance against the global average performance in that product. The Balassa index is pivotal in identifying areas of competitive strength and potential growth opportunities for nations, serving as a critical tool in the calculation of ECI and PCI. These indices, through the analytical lens provided by the algorithm and the binary matrix M, offer insightful perspectives on how countries and products are positioned within the global economic landscape, highlighting the intricate interplay between a nation's export capabilities and the inherent complexity of its export products.

$$RCA_{cp} = \frac{x_{cp}/\sum_p x_{cp}}{\sum_c x_{cp}/\sum_c \sum_p x_{cp}} \qquad (10)$$

In the matrix M used for calculating the ECI and PCI, x_{cp} signifies the exports of product p by country c. If a country lacks competitiveness or an RCA exceeding 1 for a product, M_{cp} is assigned a value of 0. This binary setup is essential for assessing the economic interactions between countries and products globally.

Aggregating the values across matrix M's rows calculates a country's economic diversity, denoted $k_c^{(0)}$. This metric indicates the number of products a country exports competitively, providing insight into the range of its export portfolio. A higher $k_c^{(0)}$ suggests a broader array of competitive exports, pointing to a diverse economy.

On the other hand, summing the values across the matrix's columns gives the ubiquity of a product, represented as $k_p^{(0)}$. This measure shows how many countries export a particular product competitively, reflecting its global availability and production. Products with higher ubiquity levels are more common and likely to face more competition, whereas those with lower levels are rarer and might indicate higher complexity.

The relationship between a country's diversity, $k_c^{(0)}$, and a product's ubiquity, $k_p^{(0)}$, offers insights into global trade dynamics and economic complexity. Countries aiming to enhance their economic complexity seek to diversify into producing and exporting products with lower ubiquity. This strategy can improve economic growth potential, as producing complex goods often demands advanced knowledge, technologies and infrastructure. The ECI and PCI thus provide a framework for understanding economic development, innovation and competitiveness internationally.

$$k_c^{(0)} = \sum_p M_{cp} \qquad (11) \text{ and}$$

$$k_p^{(0)} = \sum_p M_{cp} \qquad (12)$$

are initially determined using the method of reflections algorithm, a recursive process that begins with the calculation of diversity and ubiquity. This method iteratively adjusts these calculations, using the insights gained from one to refine the other in successive rounds. The essence of this approach lies in its capacity to enhance the accuracy of economic complexity measurements by continuously updating the diversity and ubiquity metrics based on the evolving interconnections between countries and products.

This iterative process, while seemingly straightforward, embodies a sophisticated analytical technique aimed at capturing the nuanced fabric of global trade networks. The recursive nature of the method of reflection allows for a dynamic adjustment of economic complexity assessments, reflecting changes in global trade patterns and the comparative advantages of countries over time.

Further exploration of the mathematical underpinnings of the ECI and PCI reveals that the method of reflections can be represented mathematically as equivalent to computing the eigenvalues of a modified matrix, denoted by $\widetilde{M}$**.** This matrix, $\widetilde{M}$, is structured such that its rows and columns are aligned with countries, and its entries are formulated based on a specific set of criteria derived from the initial binary matrix, M. The entries in $\widetilde{M}$ encapsulate the relationships between countries in terms of their export profiles, thereby serving as a foundation for calculating the complexity indices.

The transition from a binary representation of country-product relationships to the eigenvalue problem of $\widetilde{M}$ marks a significant methodological advancement. It provides a more rigorous mathematical basis for assessing economic complexity, leveraging linear algebra to interpret the intricate web of global exports. This approach not only facilitates a deeper understanding of the structural properties of the global economy, but also enhances the robustness and interpretability of the complexity indices. By examining the eigenvalues of $\widetilde{M}$, researchers can glean insights into the relative complexity levels of countries, identifying those that are central to the global economic network and those that occupy more peripheral positions. This mathematical framework thus enriches the analysis of economic complexity, offering a comprehensive tool for examining the sophistication and interdependence of global economic activities.

$$\widetilde{M}_{cc\prime} = \sum_p \frac{M_{cp}M_{c\prime p}}{k_c^{(0)} k_p^{(0)}} = \frac{1}{k_c^{(0)}} \sum_p \frac{M_{cp}M_{c\prime p}}{k_p^{(0)}} \qquad (13)$$

Equivalently, we can write $\widetilde{M}$ in matrix notation

$$\widetilde{M} = D^{-1}MU^{-1}M' \qquad (14)$$

The matrix D, derived from the vector of country diversity values, contains diagonal entries that correspond to the number of distinct products that a country exports with comparative advantage. This matrix serves to adjust the contribution of each country within $\widetilde{M}$, emphasising countries with a broad and diversified export portfolio. On the other hand, U is constructed from the vector of product ubiquity values, with its diagonal entries reflecting the number of countries that export a product competitively. This adjustment accounts for the commonality of products across countries, providing a measure of how widespread or unique a product is in the global market.

When these matrices are applied to $\widetilde{M}$, the result is a diversity-weighted (or normalised) similarity matrix that offers a nuanced perspective of the similarity between countries' export baskets. This adjusted matrix, $\widetilde{M}$, effectively captures the nuances of how countries are positioned in the global trade network relative to the complexity and diversity of their exports. By weighting the connections between countries and products based on diversity and ubiquity, the analysis gains depth, enabling a more accurate representation of economic complexity.

This diversity-weighted similarity matrix facilitates comparisons between countries, highlighting those with similar export profiles and distinguishing them from others with more unique compositions.

$$\widetilde{M} = D^{-1}S \qquad (15)$$

S is defined as $MU^{-1}M'$, creating a symmetric similarity matrix in which each element $S_{cc'}$ quantifies the shared products between country c and country c', with the significance of each product inversely weighted by its ubiquity. This formulation reflects the principle that products common to many countries are less indicative of a unique comparative advantage than more rare products. The construction of $\widetilde{M}$ as a row-stochastic matrix, in which each row sums to one, allows for its interpretation in the context of Markov chains, where its entries represent the probability of transitioning from one country to another based on the similarity of their export structures.

The ECI emerges from this framework as the eigenvector corresponding to the second-largest right eigenvalue of $\widetilde{M}$. This particular eigenvector is insightful, as it captures the "diffusion distance" among countries in the global trade network, effectively measuring how a country's export profile compares to others in terms of complexity. The idea of "diffusion distance" is akin to understanding how many steps, on average, it would take for a country to "transition" to the economic complexity level of another country through the Markov process described by $\widetilde{M}$.

Similarly, the PCI is derived by first transposing the initial country-product matrix M to prioritise product perspectives and then calculating the second-largest right eigenvalue of $\widehat{M}$, defined as $\widehat{M} = U^{-1}M'D^{-1}M$. This operation flips the focus of the analysis from country-centric to product-centric, allowing for an assessment of product complexity within the global trade context.

For the purposes of this paper, the vector of ECI values across countries is denoted as $\tilde{y}$, with the ECI of a specific country c represented as $\tilde{y}_c$. The diversity vector, denoted as *d*, with $d_c = kc^{(0)}$, reflects the diversity of the exports of country c', providing a baseline measure of the range of products that country c exports competitively.

To facilitate temporal and cross-sectional comparison, the ECI is typically standardised, allowing for a coherent analysis of changes in economic complexity over time and across different countries. This methodological approach underscores the nuanced interplay between country diversification, product ubiquity, and global economic complexity, offering a comprehensive lens through which to analyse and compare the economic capabilities and potential growth trajectories of nations.

4. Econometric Analysis

This econometric study delves into the influence of currency undervaluation on various facets of export performance, encompassing export value, complexity and diversity. To investigate these relationships, we employed linear regression models, both with and without the inclusion of country- and time-fixed effects. The foundational model that guides our analysis is structured as follows:

$$ExpPerf_{it} = \alpha + \beta_1 \log Underval_{it} + \beta_2 Trade_{it} + \beta_3 Gov_{it} + \varepsilon_{it} \qquad (16)$$

In this equation, $ExpPerf_{it}$ symbolises one of the trio of export performance indicators under scrutiny. The model seeks to parse out how undervaluation, trade activities and government spending each contribute to the observed export outcomes.

Building upon the methodology employed by Collier and Goderis (2012), this study also incorporates panel error-correction models to discern the short-term and long-term impacts of exchange rate undervaluation on export performance. This approach is particularly adept at testing the theoretical propositions outlined previously. The initial equation, inspired by Collier and Goderis but tailored to this study's objectives, is articulated as follows[2]:

$$\Delta ExpPerf_{i,t} = \lambda ExpPerf_{i,t-1} + \beta_1' x_{i,t-1} + \alpha_i + \delta t + \varepsilon_{i,t}, \; (17)$$

with $x_{i,t-1}$ being an $m \times 1$ vector of m variables that are expected to affect the long-run steady-state level of GDP per capita (i.e., the level of undervaluation, the ratio of trade to GDP and government spending), α_i is a country-specific fixed effect (controlling for country-specific, time-invariant unobservables), t is a time trend (that allows for a non-zero steady-state growth in output per capita), and ε is a well-behaved error term.

Collier and Goderis (2012) note that the model above allows for a study of the potential determinants of the steady-state level of the dependent variable of interest, but does not allow for the transition to the steady state to be affected by short-run fluctuations due to shocks to the economic environment. As a result, they augment the model with contemporaneous and lagged changes in $\boldsymbol{x_{i,t}}$, and a lagged dependent variable (to account for persistence in growth rates). The resulting model is then written as:

$$\Delta ExpPerf_{i,t} = \lambda ExpPerf_{i,t-1} + \beta_1' x_{i,t-1} + \beta_2 \Delta ExpPerf_{i,t-1} + \sum_{j=0}^{k} \beta_{3j}' \Delta x_{i,t-j} + \alpha_i + \delta t + \varepsilon_{i,t} \qquad (18)$$

Reformulated as an error-correction model, it becomes:

$$\Delta ExpPerf_{i,t} = a_1\left(ExpPerf_{i,t-1} + \theta' x_{i,t-1} - \mu_i - gt\right) + a_2 \Delta ExpPerf_{i,t-1} + \sum_{j=0}^{k} a_{3j}' \Delta x_{i,t-j} + a_i + a_4 t + \varepsilon_{i,t}, \qquad (19)$$

with $\lambda = a_1$, $\beta_1 = -a_1\theta$, $\beta_2 = a_2$, $\beta_{3j} = a_{3j}$, $\alpha_i = a_i - a_1\mu_i$, and $\delta = a_4 - a_1 g$. In this refined model, export performance is responsive to deviations from the long-run equilibrium, with such discrepancies propelling the economy back towards its steady state. The coefficient a_1 is expected to manifest as negative, signifying the rate at which the economy converges on equilibrium.

[2] The discussion and description of the method that follows are based largely on the discussion in Collier and Goderis (2012).

The analysis is presented systematically across tables, where configurations (1), (4) and (7) represent cross-sections; (2), (5) and (8) are augmented with time-fixed effects; and (3), (6) and (9) are further enriched by both time- and country-fixed effects. The transition from Table 3 to Table 4 is marked by the substitution of time-fixed effects with a time trend, offering a nuanced examination of the temporal dynamics influencing export performance across varying economic contexts.

Table 3: Initial Results

VARIABLES	(1) lnexp	(2) lnexp	(3) lnexp	(4) comp_i	(5) comp_i	(6) comp_i	(7) lndiversity	(8) lndiversity	(9) lndiversity
lnunderval	-0.426***	-0.648***	-0.246***	-0.476***	-0.457***	0.106	-0.271***	-0.286***	0.245***
	(0.0816)	(0.0766)	(0.0848)	(0.0330)	(0.0334)	(0.0643)	(0.0343)	(0.0345)	(0.0582)
trade_gdp	0.00635***	0.000652	0.00971***	0.00224***	0.00247***	-0.000587	6.98e-05	-0.000571***	-0.00233***
	(0.000582)	(0.000622)	(0.00202)	(0.000194)	(0.000197)	(0.000733)	(0.000203)	(0.000219)	(0.000718)
ggfc	0.0592***	0.0437***	-0.000831	0.0374***	0.0378***	0.00444	0.00969***	0.00743***	0.000929
	(0.00640)	(0.00557)	(0.00869)	(0.00261)	(0.00268)	(0.00420)	(0.00271)	(0.00268)	(0.00472)
Constant	13.84***	11.88***	15.96***	-0.713***	-0.772***	-0.0288	4.073***	3.694***	4.478***
	(0.101)	(0.229)	(0.242)	(0.0399)	(0.0991)	(0.0837)	(0.0408)	(0.0945)	(0.0899)
Observations	6 553	6 553	6 553	6 564	6 564	6 564	6 564	6 564	6 564
R-squared	0.049	0.228	0.848	0.116	0.121	0.026	0.018	0.041	0.214
F-stat	96.32	38.99	106.6	288.1	14.94	3.059	36.38	5.885	15.81
Number of count_no			161			161			161

Robust standard errors in parentheses

*** p < 0.01, ** p < 0.05, * p < 0.1

Table 4: ECM Results

VARIABLES	(1) D.lnexp	(2) D.lnexp	(3) D.lnexp	(4) D.comp_i	(5) D.comp_i	(6) D.comp_i	(7) D.lndiversity	(8) D.lndiversity	(9) D.lndiversity
L.comp_i	0.0111***	0.0101***	0.0108	-0.0268***	-0.0269***	-0.233***	-0.0140***	-0.0144***	-0.101***
	(0.00392)	(0.00391)	(0.0119)	(0.00451)	(0.00450)	(0.0187)	(0.00320)	(0.00320)	(0.0110)
LD.comp_i	0.00489	0.00452	0.00392	-0.333***	-0.333***	-0.236***	-0.105***	-0.105***	-0.0644***
	(0.0226)	(0.0225)	(0.0219)	(0.0240)	(0.0240)	(0.0182)	(0.0174)	(0.0174)	(0.0149)
L.lnunderval	0.0512***	0.0570***	0.0772***	-0.00959	-0.00886	0.0181	-0.00369	-0.00145	0.00827
	(0.0137)	(0.0138)	(0.0181)	(0.0109)	(0.0110)	(0.0204)	(0.00893)	(0.00905)	(0.0111)
LD.lnunderval	-0.0241	-0.0183	-0.0272	-0.0210	-0.0203	-0.0162	0.0346	0.0369	0.0384
	(0.0465)	(0.0465)	(0.0509)	(0.0364)	(0.0364)	(0.0362)	(0.0288)	(0.0287)	(0.0290)
L.trade_gdp	-0.000190***	-4.61e-05	-0.000376**	3.36e-05	5.20e-05	-0.000227	-5.46e-05	1.64e-06	-0.000130
	(6.32e-05)	(6.27e-05)	(0.000167)	(5.67e-05)	(5.83e-05)	(0.000214)	(4.51e-05)	(4.73e-05)	(0.000117)
LD.trade_gdp	0.000835	0.000692	0.000672	-0.000307	-0.000326	-0.000267	0.000478	0.000422	0.000470
	(0.000535)	(0.000535)	(0.000610)	(0.000455)	(0.000456)	(0.000430)	(0.000363)	(0.000364)	(0.000413)
L.ggfc	-0.000558	-0.000193	0.000459	0.000250	0.000297	0.000702	-0.000248	-0.000105	-0.000693
	(0.000848)	(0.000854)	(0.00158)	(0.000816)	(0.000825)	(0.00175)	(0.000656)	(0.000667)	(0.00110)
LD.ggfc	0.00489	0.00427	0.00416	-0.000637	-0.000717	-0.00109	0.00127	0.00103	0.00113
	(0.00546)	(0.00547)	(0.00570)	(0.00264)	(0.00265)	(0.00208)	(0.00211)	(0.00212)	(0.00184)
year		-0.00178***	-0.00182***		-0.000229	-0.000252		-0.000697***	-0.000730***
		(0.000228)	(0.000232)		(0.000209)	(0.000343)		(0.000171)	(0.000192)
Constant	0.101***	3.636***	3.742***	-0.00657	0.448	0.512	0.0162	1.401***	1.487***
	(0.0142)	(0.453)	(0.450)	(0.0131)	(0.414)	(0.682)	(0.0103)	(0.339)	(0.377)
Observations	6 225	6 225	6 225	6 235	6 235	6 235	6 235	6 235	6 235
R-squared	0.008	0.017	0.018	0.130	0.130	0.201	0.028	0.030	0.052
F-Stat	3.094	9.326	17.21	35.12	31.50	64.34	9.733	10.96	16
Number of count_no			161			161			161

Robust standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

In the analysis of Table 3, the variable $lnunderval$ consistently demonstrated a significant relationship with our dependent measures. Specifically, a negative correlation with $lnexp$ emerged across all models (columns 1 to 3). While its association with comp_i revealed significance and a negative trend in columns (4) and (5), this was not the case for column (6). For the variable lndiversity, $lnunderval$ exhibited a significant negative relationship in columns (7) and (8), but intriguingly, a positive significant relationship in column (9). On the other hand, the variable trade_gdp manifested a varied relationship. It showed a significant positive association with $lnexp$ in columns (1) and (3), but a nuanced relationship with comp_i and $lndiversity$, ranging from positive, *near-zero*, to negative associations, contingent on the model.

Turning our attention to investment ($ggfc$), a positive significant relationship with $lnexp$ was revealed in columns (1) and (2). Its correlation with comp_i was noteworthy in columns (4) and (5), yet lacked significance in column (6). Regarding $lndiversity$, $ggfc$ had a positive and significant relationship in columns (7) and (8), but was not $significant$ in column (9). The R-squared values of the model varied substantially. We see a high explanatory power in column (3) for $lnexp$, accounting for 84.8% of its variance. In contrast, the model only explained 2.6% of the variation in comp_i in column (6), indicating the need for further variables or refined modelling in specific scenarios.

Table 4 presents the outcomes of regression models analysing the effects of various lagged (L.) and lagged difference (LD.) independent variables on the first differences of three dependent variables: $D.lnexp$, $D.comp\_i$ and $D.lndiversity$.

Firstly, for D.lnexp, the lagged value of $comp\_i$ (L.comp_i) showed a significant positive effect in columns (1) and (2). The lagged value of $lnunderval$ (L.lnunderval) also indicated a positive and significant effect across all three columns. It is worth noting that the variable $L.trade\_gdp$ exhibited a significant negative effect in columns (1) and (3). The inclusion of the $year$ variable in column (2) had a significantly negative coefficient, suggesting a decrease in the dependent variable over time.

Secondly, focusing on $D.comp\_i$, the $L.comp\_i$ variable showed a consistent negative relationship in all three columns, with a powerful and significant effect in columns (4) and (5). Furthermore, the lagged difference of $comp\_i$ ($LD.comp\_i$) registered significant negative coefficients across the board. However, both $L.lnunderval$ and $LD.lnunderval$ lacked significance in this context, implying a weaker or non-existent relationship with changes in $comp\_i$.

Lastly, when analysing $D.lndiversity$, $L.comp\_i$ exhibited a strong negative effect across the three columns. The $LD.comp\_i$ variable also presented a consistently negative and significant relationship. The year variable indicated a negative trend in columns (8) and (9). R-squared values varied with the model, explaining up to 20.1% of the variance in $D.comp\_i$ in column (6), but only up to 5.2% in $D.lndiversity$ in column (9). Overall, the significance of various coefficients emphasises the need to account for lagged effects when analysing changes in our dependent variables.

5. Interpretation of the Results

This analysis examined global economic indicators, focusing on their influence on exports, economic complexity, and diversity. It used a dataset that encompasses 151 countries from 1962 to 2009, with many observations – ranging from 6 225 to 6 564. This comprehensive exploration shed light on the interconnectedness of economic trends, providing a deeper understanding of how different economic factors interact.

Unexpectedly, the study uncovered a series of negative correlations; particularly striking was the relationship between currency undervaluation (represented by the $lnunderval$ variable) and exports. This finding poses a challenge to the widely held assumption that a depreciated currency value automatically leads to an improvement in export performance. Instead, it raises the possibility that currency undervaluation could be associated with elements that negatively affect export growth, challenging the conventional debate.

The analysis also engaged with key academic contributions from Agosin et al. (2012), Berg and Miao (2010), Levy-Yeyati et al. (2013) and Sekkat (2016), who collectively express scepticism towards the simplistic linkage often drawn between exchange rate misalignment and broader economic growth or diversification outcomes. Specifically, their examination of how exchange rate misalignments affect export diversification, especially in the manufacturing sector, aligns with our findings by demonstrating a lack of conclusive evidence to support the expected positive effects of such misalignments.

Moreover, the observed negative correlations, most notably between currency undervaluation and various measures of economic performance, suggest that the influence of currency devaluation may depend on specific economic conditions, such as whether the economy is oriented towards profit-led growth, and could be substantially moderated by both institutional and contextual factors within a country. This idea, which has been underscored in the analyses of Ribeiro et al. (2016) and Rodrik (2008), points to the complexity of economic dynamics and indicates that the institutional settings across different countries might play a crucial role in shaping the outcomes observed in our study. This nuanced understanding calls for reevaluating existing economic models and strategies, considering the intricate web of factors that influence economic performance in the global landscape.

The analysis further explored the ramifications of currency undervaluation on the costs associated with importing intermediary inputs and capital goods, which are essential components in the production of sophisticated final products. This aspect of the economic debate, highlighted by the work of Aghion et al. (2009) and Elbadawi et al. (2012), finds resonance in our observation of a negative correlation between currency undervaluation and the level of economic complexity within a nation's export portfolio. The implication here is that the perceived benefits of maintaining a currency at a value lower than its supposed market equilibrium to enhance the competitiveness of exports may not yield the anticipated outcomes of advancing the complexity and diversification of a country's exports. This complexity challenges the conventional narrative, suggesting a re-evaluation of the strategies to achieve economic development through currency manipulation.

In addition, our results align with Heckman's (2008) critical perspective on the nuanced distinction between correlation and causality, particularly in the context of our findings, where the direct link between currency undervaluation and the broadening of export diversification fails to conform to established economic theories. This mismatch underscores the existence of a multifaceted network of economic interactions that transcend simple cause-and-effect assumptions. Our findings, indicating a non-linear and intricate relationship between currency valuation and export outcomes, underscore the necessity of adopting a more granular approach when analysing economic policies and their impacts. This nuanced understanding advocates for a cautious interpretation of economic data, where the dynamics of currency valuation are considered within the broader spectrum of influencing factors and their potential ripple effects across the economy.

In summary, our study explored economic complexity and diversity, revealing that undervaluation does not always enhance economic sophistication, thus questioning the conventional link between currency valuation and economic complexity. It examined the trade-to-GDP ratio and the proportion of GDP in general government consumption expenditure (ggfc), showing their complex and sometimes paradoxical relationship with key economic performance metrics. This analysis highlights the dynamic and sometimes unexpected nature of these relationships. In addition, the study emphasises the importance of lagged variables, showing how past economic conditions can hinder current efforts to boost exports, complexity and diversity. This insight calls for a deeper understanding of how historical economic patterns influence present economic outcomes, suggesting that enhancing economic complexity and diversity is affected by many factors, including – but not limited to – currency valuation, trade intensity, and government fiscal practices.

6. Conclusion

This research explored the interactions between real exchange rate (RER) misalignments and economic complexity across a range of countries. By utilising a panel vector autoregression (VAR), we explored the effects of RER deviations on export diversification, scrutinising this through the lens of export volume, the complexity of economic activities, and the diversity of products exported.

We see puzzling results. While it is generally believed that RER misalignments enhance exports and contribute to greater economic complexity, our analysis showed nuanced results. The effect of RER misalignments varied significantly across different analytical models, some devoid of fixed effects and others incorporating adjustments for both country-specific and time-related variations.

A particularly striking finding from this investigation is the lasting influence of RER misalignments on the economic structure of countries. Far from being short-term fluctuations, these misalignments have the potential to shift the path of export diversification fundamentally. This shift, however, does not always align with the expected increase in economic complexity and diversity. Instead, the effect is multifaceted, influenced heavily by the unique economic, institutional and socio-political context of each country.

It is critical to approach these findings with a degree of humility, recognising the intricate nature of the economic systems under investigation and the inherent limitations of our study. Although our research adds to the ongoing discourse on the effects of RER misalignments on export diversification and economic complexity, we acknowledge that our work represents only a single contribution to a broader and highly complex discussion.

With this in mind, we view our findings as a foundation for further research. Future directions for this work include conducting additional robustness tests, exploring alternative economic complexity indicators, and adopting a more detailed categorisation of our dataset to differentiate between countries at different stages of development, regional economic dynamics, and the influence of various industrial sectors on GDP. These results deepen our comprehension of the dynamic forces shaping the global economy, providing valuable insights for policymakers, economists and academics as they navigate the complexities and opportunities associated with RER misalignments – all to foster sustainable economic growth and diversification.

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