

# International product life cycles, trade and development stages

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**Abstract** In this paper we first propose a proxy for early stage activity in a country's exports based on product life cycle theory. Employing a conditional latent class model, we then examine the relationship between this measure and economic growth for 93 countries during the period 1988–2005. We find that the impact of early stage activity differs across three clusters of countries. And we find that GDP levels can predict the cluster and the sign of the coefficient in a non-linear manner. In the richest countries, exporting products that are in an early stage of their product life cycle is associated with higher growth rates. In contrast, we find a cluster of middle income countries with high growth rates that grow faster by exporting more mature products that are in the later stages of their life cycle. Finally, early stage activity has no significant impact on growth in the cluster of the poorest, developing countries. Countries in early stages of development should focus on acquiring market share in mature markets with routine technologies whereas emerging economies face the challenge of at some point switching from copying mature to inventing new products as they approach the global technology frontier. At that frontier they must join the advanced economies who specialise in early stage innovative products to stay ahead of increasing competition from abroad.

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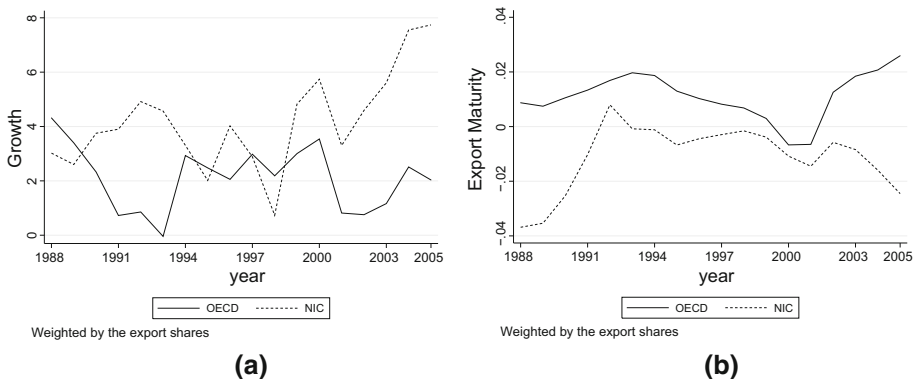
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## 1 Introduction

Ever since Adam Smith linked specialisation and trade to the wealth of nations, trade and competitiveness in international markets has been considered a key driver for development and national well being. For that reason trade has been subject of intense academic and policy interest. Using strategic trade- and industrial policies governments across the world try to push their countries up in the league of nations. It has been found that specialising in the “right” products and markets helps countries move ahead, whereas a focus on the “wrong” export bundle can keep a nation trapped in poverty (e.g. Redding 2002; Bensi-doun et al. 2002; Hausmann et al. 2007). But despite the fact that much of the academic literature on this topic stresses the dynamic nature of comparative advantage, to date it fails to consider that “right” and “wrong” are not absolutes. In this paper we argue that the “right” products in emerging countries may well be different from the “right” products in advanced economies. Moreover, the bundle of “right” and “wrong” products will change over time as products mature over their life cycle. It makes quite a difference if you, for example, specialise in video cassette recorders (VCRs) in the early 1980s or in the late 2000s. And it matters a lot also if you do so when you are an emerging economy starting to industrialise or when you are an advanced country at the global technology frontier.

Taking a more dynamic approach to specialisation will go a long way in explaining some of the most salient features of global economic development in recent decades. This point is illustrated using Fig. 1a. It shows that growth in the OECD countries was depressed in the early 90s and 00s and has not reached more than 4% since 1988. The Newly Industrialising Countries (NIC) by contrast show a period of volatile and relatively low growth in the mid 90s and a strong recovery after 2000 with (average) growth rates reaching 7%. Over this period, we also know the NICs, and most notably China, have



**Fig. 1** Economic growth and export maturity. *Note* both graphs are weighted by the country share in world exports, based on authors’ own calculations. Growth is expressed in percentage points in **a**. Export maturity is an index number. The higher the export maturity, the younger the export bundle is **b**

integrated in global markets and increased their volume and share in global trade (OECD 2005). These developments can be linked to the dynamics in the global pattern of specialisation in general and the composition of exports over product life cycle stages in particular (Audretsch and Sanders 2007). Figure 1b shows how OECD countries have indeed maintained a comparative advantage in young, less mature products, whereas emerging economies rapidly closed the gap over the early 90s but NICs remain specialised in more mature markets, increasingly so since 2000. But the figure does not tell an unambiguous story and the challenge is to find an adequate measure of life cycle maturity at the product level.

The purpose of this paper is to propose such a measure for product maturity and using that measure to investigate the heterogeneous relationships between export maturity and economic growth across a wide range of developing and developed countries. In doing so we make two contributions to the literature.

The first contribution lies in our index that captures the average maturity of a country's export mix. To date the lack of such a measure has prevented scholars from analysing comparative advantage and specialization patterns over product life cycle stages in global trade. To enable such an analysis, we introduce a product-specific maturity measure using a well established empirical regularity over the product life cycle (e.g. Hirsch 1967; Vernon 1966; Klepper 1996). Over the typical life cycle total sales in the relevant market first increase at an increasing rate, then at a decreasing rate and finally decline. Following Hirsch (1967), Audretsch (1987) and Bos et al. (2013), we therefore proxy for the life cycle stage of a product by the first (growth) and second (growth in growth) moment in its global total export volume. We then calculate an aggregate maturity measure for a country's export bundle by weighing the product maturity by the shares of these products in a country's export mix. With this proxy, we are thus able to explore whether and how the maturity of a country's export bundle matters for its economic performance. Our new measure allows us to build on an older literature that links the product life cycle to trade and growth.<sup>1</sup>

The second contribution of this paper is to employ a conditional latent class model to estimate our growth regression. To the best of our knowledge, this approach is quite new to the trade and growth literature and it brings several advantages over more standard econometric techniques. First, instead of *ex ante* assuming the number of countries in various growth regimes and then using the data to verify that assumption, we turn the procedure around and let the data tell us how many different regimes best fit our data. All we need to assume in this model is that growth may depend on export maturity and other, more conventional growth determinants. We then show that the level of development, proxied by GDP per capita, has explanatory power predicting in which of the endogenously determined regimes our countries fall. Second, the latent class model allows for parameter heterogeneity. Addressing heterogeneity has become one of the most debated issues in the growth literature (Temple 1999; Durlauf et al. 2005) and in light of this issue, conventional empirical approaches have often been deemed unsatisfactory.<sup>2</sup> In short, our modelling approach enables us to avoid the pitfalls of imposing a common relationship between

<sup>1</sup> See Mullor-Sebastian (1983) for an overview of the early empirical literature on the product life cycle in the 60s.

<sup>2</sup> The most common practice is to include regional dummies or country fixed effects in a panel framework. The major drawback of these approaches is that they do not allow for differences in the marginal effect of regressors across regimes. Our conditional latent class model estimates regime-specific parameter vectors. In other words, countries in the same regime share a common parameter vector, but this vector is allowed to differ across regimes.

export maturity and growth for all countries but yields results that are comparable across countries and time. Our approach is closely related to recent studies that apply conditional latent class (or finite mixture) models to examine the heterogeneity of growth and convergence patterns across countries.<sup>3</sup>

In our study we apply our method to Statistics Canada's version of the UN-COM-TRADE database that contains the export data on 427 Standard International Trade Classification (SITC) four-digit products for 93 countries over the period 1988–2005. This database gives us the opportunity to zoom in on relatively narrowly defined groups of products and generalise trade patterns across more countries than most studies to date. We thus propose a simple measure of product maturity in the global market and then link the overall average maturity of a country's export portfolio to their economic growth performance.

Our results are easy to summarise. We find that developed countries (with high GDP per capita) are exporting products in the early stages of their (global) life cycle, whereas the opposite is true for developing countries. In addition, we find evidence for the existence of three quite distinct growth regimes. For the advanced countries' regime, exporting new and innovate products is associated with higher economic growth, whereas this relationship is insignificant for the developing countries' (lowest GDP per capita) regime. In stark contrast, we identify an emerging countries' regime where exporting more mature products appears to be associated with more rapid growth. These findings have important implications for trade and economic development theory and policies. Notably, our results suggests we can look at specialization and dynamic comparative advantage as an advantage in exporting goods and services in a given stage of the life cycle. Advanced economies do not have a comparative advantage in computers or machinery, but in early stage products. Likewise, emerging economies have a comparative advantage in mature products. The early stage products of a decade ago, however, are today's mature products. And product classes (i.e. telephones) can be rejuvenated through innovation. Taking such an approach to economic development has clear implications for policy. Advanced economies should focus their efforts and resources on shifting out the global technology frontier, whereas emerging economies will prosper by capturing existing, mature markets.

The remainder of the paper proceeds as follows. First we position our paper in the relevant literatures on trade and growth in Sect. 2. In Sect. 3 we present a stylised model of trade and product life cycles to derive our key hypothesis. Note that this paper does not aim to make a theoretical contribution and the model is merely presented to provide a framework in which to interpret our empirical results. In Sect. 4, we develop our maturity proxy and discuss our data and estimation strategies. The empirical results are then presented in Sect. 5. And Sect. 6 discusses the implications of our paper and concludes.

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<sup>3</sup> Specifically, Paap et al. (2005) apply a latent class analysis to sort a number of developing countries according to their average growth rates over the period 1961–2000. Alfo et al. (2008) develop a mixture of cross-sectional growth regression to uncover multiple regimes of per capita income convergence across EU regions for the period 1980–2002. Owen et al. (2009) apply a conditional finite mixture model based on the similarity of the conditional distribution of growth rates for a broad set of countries for the period 1970–2000, and find evidence of two distinct clubs, each with its own distinctive growth dynamics and institutional quality is a good predictor of the club membership. Bos et al. (2010) estimate a latent class production frontier and uncovers three different growth regimes using human capital, openness to trade, financial development, and the primary sector share as regime predictors for a sample of 77 countries during the period 1970–2000. Vaio and Enflo (2011) support that growth patterns were segmented in two worldwide regimes, the one characterised by convergence in per capita income, and the other by divergence based on a sample of 64 countries over a very long horizon 1870–2003. Owen and Videras (2012) use latent class analysis to characterise development experiences of countries by taking into account the quality of growth.

## 2 Literature review

Our paper builds on recent advances in two long traditions in the literature. The first strand, pioneered by Vernon (1966), applies stylised life cycle models to explain the shift of dynamic comparative advantages and the evolution of trade patterns over time (Hirsch 1967; Krugman 1979; Jensen and Thursby 1986; Kellman and Landau 1984; Dollar 1986; Flam and Helpman 1987; Grossman and Helpman 1991; Lai 1995). An important prediction in this line of literature is that developing countries will increasingly compete in those products that reach the later stages of the product life cycle, implying that the advanced economies must “run to stand still” (Krugman 1979). A steady flow of new product innovations is necessary to maintain international income differentials. In these models the assumed relative abundance of cheap, unskilled labour in the less developed South is the source of a dynamic comparative advantage in copying mature products and technologies from the more advanced North. If, in such a context, globalisation and trade integration imply that populous developing economies enter global market competition, then advanced economies experience a shift of their comparative advantage towards products that are in the earliest stages of the product life cycle (see e.g. Lai 1995; Audretsch and Sanders 2007).

The second strand of literature relevant to our work extensively documents the effect of trade, and more specifically exports, on economic growth. The vast bulk of the early empirical literature asks: “Do Exports Matter?”.<sup>4</sup> Most of these studies include either a measure of export (growth) or trade openness in a standard regression framework covering a wide range of countries, time periods and using a variety of estimation techniques. Consistent with the difficulties in establishing robust empirical evidence linking growth to fundamentals in general (Temple 1999; Durlauf et al. 2005), the evidence is rather mixed. Some find a significant positive relationship between export (growth) and per capita GDP growth, while others caution us not to assign the direction of causality (Rodriguez and Rodrik 2001). An interesting contribution by Moschos (1989) hinted at the existence of different regimes in the relationship between exports and growth. A salient feature of this literature is that the measure of export/trade openness is typically broadly defined. As a result, the channels through which international trade influences economic growth remain unclear and possible heterogeneity over different development stages remains hidden.

A number of studies do examine the relationship between the structure of exports and long-term economic performance in more detail and asks: “How do Exports Matter?”.<sup>5</sup> In particular, this literature has focused on the relationship between export diversification and growth (E.g. de Pineres and Ferrantino 1997). Export diversification is widely seen as a desirable trade objective in promoting economic growth (Herzer and Nowak-Lehmann 2006). Diversification makes countries less vulnerable to adverse terms of trade shocks. By

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<sup>4</sup> This literature is massive. Giles and Williams (2000) provides a comprehensive survey of more than 150 papers that test the export-led growth hypothesis alone. Singh (2010) provides a recent survey of a growing body of studies that explore linkages between trade openness and growth.

<sup>5</sup> The structure of imports may have direct impact on economic performance as well. Earlier studies show that imports of quality foreign capital goods serves as a means to acquire foreign technology through reverse engineering (Connolly 1999). Lee (1995) and Lewer and Berg (2003) find that capital-importing countries benefit from trade because trade causes the cost of capital to fall, where Schneider (2005) shows that high technology imports matter for growth. However, others do not reveal any significant role for the composition of imports in economic growth (An and Iyigun 2004; Wörz 2005). In line with recent papers that analyse the importance of export structure for better economic performance, this paper focuses on the export side and leave the import side for future research.

stabilising export revenues it is then easier to channel positive terms of trade shocks into growth, knowledge spillovers and increasing returns to scale, creating learning opportunities that lead to new forms of comparative advantage.<sup>6</sup> In a dynamic growth framework, some recent studies have uncovered a non-linear link between export diversification and economic growth (Aditya and Roy 2007; Cadot et al. 2007; Hesse 2008; Xuefeng and Yasar 2016). The main insight is that developing countries benefit from diversifying their exports, whereas developed countries perform better with export specialisation.<sup>7</sup> What remains unclear from this literature, however, is whether the mix of particular products, diversified or specialised, has any implications for growth.

That raises the question: “Does What We Export Matter?” and our paper is close to a handful of studies that have started to address that question by zooming in on the specific characteristics of exports in relation to economic performance.<sup>8</sup> The earliest studies distinguish between primary sector and manufacturing exports. Exporting primary products, which suffer from unfavourable price trends and from great price variability, are suspected to associate poor growth performance (Rodríguez and Rodrik 2001), whereas the expansion of manufactured exports has been a vital source of growth for many countries (Cline 1982; Ranis 1985; Martin 1993; Cline 2010). Thanks to the increasing availability of highly disaggregated trade data, first in the OECD and then for other parts of the globe, the research focus has recently shifted to the product characteristics of exports. Dalum et al. (1999) demonstrate that exports with higher levels of technological opportunity and higher income elasticities are associated with better growth prospects among OECD countries. Feenstra and Rose (2000) developed a procedure to order countries according to how soon they export advanced commodities to the US market and find that countries exporting sooner to the United States tend to grow faster. Bensidoun et al. (2002) show that countries specialising in products for which the share in international trade has increased grow faster than those that maintained a comparative advantage in stable or declining products. An and Iyigun (2004) compute the skill content of exports based on the US industry-wide R&D expenditures as a share of gross sales revenue as the benchmark. They show that a higher skill content of exports correlates with a higher growth rate. Lee (2011) adds to the evidence that countries have tended to grow more rapidly when they have increasingly specialised in exporting high-technology as opposed to traditional or low-technology goods and Jarreau and Poncet (2012) shows that export sophistication drives growth also at the regional level in China. Last but not least, a small number of recent papers examines how the network structure of economic output influences a country’s overall wealth and development (Hidalgo et al. 2007; Hidalgo and Hausmann 2009; Hausmann and Hidalgo 2011). For example, Hidalgo et al. (2007) present the network of relatedness between products, i.e. the “product space” and reveal that the types of products a country currently produces determine the probability of that country developing more competitive products in the future. This may help explain the lack of economic convergence of poor countries as they failed to produce more advanced goods.

A seminal study by Hausmann et al. (2007) develops a theoretical model where local cost discovery generates knowledge spillovers to show that a country’s specialisation

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<sup>6</sup> In a similar vein, export concentration is found to be associated with slow growth, in particular when export concentration reflects the predominance of primary products (Sachs and Warner 1995; Gylfason 2004; Klinger and Lederman 2006).

<sup>7</sup> This finding is consistent with Imbs and Wacziarg (2003) who find a similar pattern using production and employment data.

<sup>8</sup> See Lederman and Maloney (2012) for an extensive review.

pattern becomes partly indeterminate in the presence of such externalities. They conclude from this that the mix of goods that a country produces may therefore have important implications for economic growth and construct a product-specific sophistication measure based on the income of the average exporter. They then test their hypothesis and find that exporting more sophisticated products is positively associated with subsequent growth.

Building on these recent studies, we propose not to focus on a static product sophistication measure but rather on a product's life cycle stage in the global market. This has important implications. With age, a product matures and becomes less sophisticated. In addition, instead of postulating a development strategy for developing countries that should shoot for the stars and export what the developed countries are exporting, we argue this may not be optimal. Developing countries may lack the capability to produce complex products (Indjikian and Siegel 2005).<sup>9</sup> Therefore, our paper advocates a development strategy that is better tuned to the development stages of countries. But let us first develop our arguments a bit more formally.

### 3 A simple model adapted from Grossman and Helpman (1991)

Assume we can divide the world in two regions. And advanced "North" and emerging "South". Consumers in these two regions consume a variety of  $n$  goods, indexed by  $i$  where utility in both regions is given by:

$$U = \sum_{i=0}^n c_i^\alpha \quad (1)$$

where  $U$  is a utility index,  $c$  is consumption and  $\alpha$  is a parameter between 0 and 1. Global demand for good  $i$  is then equal to:

$$c_i^D = p_i^{\frac{1}{\alpha-1}} \frac{E}{P} \quad (2)$$

where  $p_i$  is the price of good  $i$ ,  $E$  is global expenditure on consumption and  $P$  is a price index defined as  $P \equiv \sum_{i=0}^n p_i^{\frac{\alpha}{\alpha-1}}$ . We assume that production follows a simple linear production function in labor only, such that marginal production costs equal wages. Labor is assumed immobile across regions but mobile across firms within a region, such that wages are region specific and given to all firms. Firms produce a single variety  $i$ . We assume they own tacit and proprietary knowledge that enables them to do so and consequently they are price setters in their product market. Any product, however, can be imitated at some fixed start-up cost. This implies we have four groups of products. New,  $i \in A_{N,S}$  and mature  $i \in M_{N,S}$  products produced in North and South, respectively. We assume that new products require high skilled labor whereas mature products can also be produced with low skilled labor. The profit maximisation problem for the producer is given by:

<sup>9</sup> Indjikian and Siegel (2005) provide a comprehensive review on the impact of IT on economic performance in developed and developing countries. They find strong positive correlation between IT and economic performance in developed countries, but not in developing countries. They argue that two deficiencies hinder the use of IT in developing countries are the lack of knowledge of "best practice" and IT-skilled labour force.

$$\begin{aligned}
 \max_{p_i} : \quad & \pi_i = p_i y_i - w_C^S l_i^S \\
 \text{subject to} \quad & y_i = c_i^D \\
 & y_i = l_i^H, i \in A_C \\
 & y_i = l_i^L, i \in M_C
 \end{aligned}
 \tag{3}$$

where  $C$  indexes the regions ( $N$ )orth and ( $S$ )outh and  $S$  the skill levels ( $H$ )igh and ( $L$ )ow. It is straightforward to show that all firms will set their price equal to:

$$p_i = \frac{1}{\alpha} w_C^S
 \tag{4}$$

We assume for simplicity that  $\frac{w_C^L}{\alpha} < w_C^H$  such that all producers can set their prices freely.<sup>10</sup> Let us first solve the model statically, that is, for a given portfolio of goods in the ranges  $A_N, M_N, A_S$  and  $M_S$ . As costs are equal within these ranges, so are prices and demanded quantities. Labor demand for high and low skilled labor in South and North can be set equal to exogenous supply to yield:

$$\begin{aligned}
 L_N^{L*} &= \sum_{i=0}^n c_i(p_i(w_N^L)) = M_N \left(\frac{w_N^L}{\alpha}\right)^{\frac{1}{\alpha-1}} \frac{E}{P} \\
 L_N^{H*} &= \sum_{i=0}^n c_i(p_i(w_N^H)) = A_N \left(\frac{w_N^H}{\alpha}\right)^{\frac{1}{\alpha-1}} \frac{E}{P} \\
 L_S^{L*} &= \sum_{i=0}^n c_i(p_i(w_S^L)) = M_S \left(\frac{w_S^L}{\alpha}\right)^{\frac{1}{\alpha-1}} \frac{E}{P} \\
 L_S^{H*} &= \sum_{i=0}^n c_i(p_i(w_S^H)) = A_S \left(\frac{w_S^H}{\alpha}\right)^{\frac{1}{\alpha-1}} \frac{E}{P}.
 \end{aligned}
 \tag{5}$$

We can now solve for equilibrium wages and express profits in product portfolio ranges, exogenous labor supplies and parameters only.

$$\begin{aligned}
 \pi_{A_N} &= \frac{(1-\alpha)E}{A_N} \frac{A_N^{1-\alpha} L_N^{H*\alpha}}{A_N^{1-\alpha} L_N^{H*\alpha} + M_N^{1-\alpha} L_N^{L*\alpha} + A_S^{1-\alpha} L_S^{H*\alpha} + M_S^{1-\alpha} L_S^{L*\alpha}} \\
 \pi_{M_N} &= \frac{(1-\alpha)E}{M_N} \frac{M_N^{1-\alpha} L_N^{L*\alpha}}{A_N^{1-\alpha} L_N^{H*\alpha} + M_N^{1-\alpha} L_N^{L*\alpha} + A_S^{1-\alpha} L_S^{H*\alpha} + M_S^{1-\alpha} L_S^{L*\alpha}} \\
 \pi_{A_S} &= \frac{(1-\alpha)E}{A_S} \frac{A_S^{1-\alpha} L_S^{H*\alpha}}{A_N^{1-\alpha} L_N^{H*\alpha} + M_N^{1-\alpha} L_N^{L*\alpha} + A_S^{1-\alpha} L_S^{H*\alpha} + M_S^{1-\alpha} L_S^{L*\alpha}} \\
 \pi_{M_S} &= \frac{(1-\alpha)E}{M_S} \frac{M_S^{1-\alpha} L_S^{L*\alpha}}{A_N^{1-\alpha} L_N^{H*\alpha} + M_N^{1-\alpha} L_N^{L*\alpha} + A_S^{1-\alpha} L_S^{H*\alpha} + M_S^{1-\alpha} L_S^{L*\alpha}}.
 \end{aligned}
 \tag{6}$$

Such that total profit in the economy adds up to  $(1-\alpha)$  times total expenditure. Also note that the profit in any given product range is falling in all product ranges. These profits,

<sup>10</sup> One should realise that, since advanced producers in the same or the other region can compete and will produce when their marginal costs are below the market price. This caps the price of mature goods at  $w_C^H$ . We assume here that this constraint is not binding, even for the mature product producers in the North imitating their product from the South. We thus assume:  $\frac{w_C^L}{\alpha} < > \frac{w_C^H}{\alpha} < w_C^H < > w_N^H$ .



however, are also strictly positive and provide an incentive to innovate (create new products) and imitate (switch a product from advanced to mature). In this economy the only long run source of economic growth is this expansion of the goods ranges. We can show that a steady state can only exist when all goods ranges expand at a common growth rate. Note from Eq. 6 that if all goods ranges expand at a common rate,  $g$ , we see that profits in an individual firm will fall at a constant rate equal to the growth rate of expenditure minus  $g$ . Setting the former to 0 by normalising expenditure to 1 we obtain  $-g$  for the growth rate of profit. The value of a new firm in either goods range will be equal to the discounted profit flow over the expected remaining lifetime of the firm. For mature goods we assume this lifetime to be infinite and the value of a firm producing an mature good in country  $C$  is:

$$V_{M_C}(t) = \int_t^\infty e^{-r\tau} \pi_{M_C}(\tau) d\tau = \int_t^\infty e^{-(r+g)\tau} \pi_{M_C}(t) d\tau = \frac{\pi_{M_C}(t)}{r+g}. \tag{7}$$

For advanced goods it is slightly more complicated, as the profit flow ends when the product is imitated. However, if we assume the expected flow probability of that happening is constant in the steady state at  $h$  we can compute the value of a new firm as:

$$V_{A_C}(t) = \int_t^\infty e^{-(r+h)\tau} \pi_{A_C}(\tau) d\tau = \int_t^\infty e^{-(r+h+g)\tau} \pi_{A_C}(t) d\tau = \frac{\pi_{A_C}(t)}{r+h+g}. \tag{8}$$

We endogenise innovation and imitation as in e.g. Grossman and Helpman (1991) and Audretsch and Sanders (2007) by assuming R&D firms can employ R&D resources to innovate according to:

$$\dot{A}_C = A_C^\gamma M_C^{1-\gamma} R_C^R \tag{9}$$

where the dot signifies a time derivative and the Cobb–Douglas aggregate of  $A_C$  and  $M_C$  represents the knowledge stock and  $0.5 < \gamma < 1$  would imply more recent knowledge is given more weight, while  $R_C^R$  is R&D resources allocated to the creation of new products. Likewise we assume imitation takes place according to:

$$\dot{M}_C = A_C^\delta A_{-C}^{1-\delta} R_C^D \tag{10}$$

where  $A_{-C}$  is the range of imitable advanced products *not* in country  $C$  and so the relevant knowledge base is a Cobb–Douglas aggregate of domestic and foreign imitable products and  $0.5 < \delta < 1$  would imply it is easier to imitate from home. We can compute the marginal value product of R&D resources in imitation and innovation by multiplying the derivative of Eqs. (9) and (10) with respect to R&D labor by the value of a new or mature firm in country  $C$  in Eqs. (8) and (7), respectively. Substitution for profits using Eq. (6) in both countries and dividing the resulting expressions on each other we obtain:

$$\begin{aligned} \frac{r+h+g}{r+g} &= A_N^{-\alpha+\gamma-\delta} A_S^{\delta-1} M_N^{1-\alpha-\gamma} \left( \frac{L_N^H}{L_N^*} \right)^\alpha \\ \frac{r+h+g}{r+g} &= A_S^{-\alpha+\gamma-\delta} A_N^{\delta-1} M_S^{1-\alpha-\gamma} \left( \frac{L_S^H}{L_S^*} \right)^\alpha \end{aligned} \tag{11}$$

as R&D arbitrage conditions for North and South respectively. This arbitrage condition allows us to derive some comparative statics on the steady state, in which the left hand side is equal for both regions. We then obtain:

$$\left(\frac{L_N^H L_S^L}{L_N^L L_S^H}\right)^\alpha \left(\frac{M_N}{M_S}\right)^{2(1-\delta)} = \left(\frac{A_N M_S}{M_N A_S}\right)^{-1+\alpha-\gamma+2\delta} \quad (12)$$

which must hold in the steady state. This equation implies that for  $\alpha - \gamma + 2\delta > 1$  all powers are positive.<sup>11</sup> Hence an increase in the left term, a rise in the *relative* skilled labor abundance in the North, we will see a drop in the relative diversity in the North in the middle and/or a rise in the relative specialisation in early stage products in the North on the right. That is, the North will tend to specialise in advanced products and the South will diversify its production by expanding its mature goods range. In the steady state the North will specialise in advanced, early stage products and services, whereas the South will specialise in imitated, mature products.

This also suggests (but does not yet imply) that out of steady state a more advanced country will have above steady state growth when moving towards a more innovative and advanced output bundle. We argued in Audretsch and Sanders (2007) that the fall of the Berlin wall and market reforms in Latin America and Asia upset the old steady state in the global economy and drew and pushed Europe and the US into a less mature export portfolio. In the model above, the political shocks can be interpreted as an expansion of the Southern labor force, especially in its low skilled labor supply, at least initially. Such a shock shifts the steady state composition of the product ranges and given that a low skilled labor supply shock in the South increases the value of imitation in the South, even from the North, the adjustment to the new steady state will only coincide with positive growth in the North if it can successfully increase its range of advanced products through innovation. Growth in the South, in contrast, will result from imitation and the capture of market share in mature goods and services.

Note that in this slightly adapted setup of Grossman and Helpman (1991) we derived this specialisation pattern endogenously.<sup>12</sup> We now turn to the empirical evidence in support of our hypothesis.

## 4 Data and methodology

In this section we first develop a measure of product maturity drawing on the insights from product life cycle theory and then compute the average maturity of our countries' export portfolios. We then present the estimation strategy, as well as the data before turning to our results in Sect. 5.

### 4.1 Measuring product maturity

Our measure of product maturity is based on one of the well established empirical regularities found in the product life cycle literature. Total sales of a product in the market first increase at an increasing rate, then at a decreasing rate and finally decline, tracing out an S-shaped diffusion curve (Klepper 1996). We therefore want to develop our measure of

<sup>11</sup> As for higher  $\alpha$  the price elasticity of demand increases and prices converge on marginal costs a higher  $\alpha$  reflects more intense competition in global markets. Also recall that  $\gamma$  reflects the innovation output elasticity with respect to recent (vs old) knowledge, whereas  $\delta$  reflects the ease of adopting domestic versus foreign advanced technology. As long as  $\alpha$  is above 0.5 and  $\delta > \gamma$  our condition is satisfied.

<sup>12</sup> In Krugman (1979) and Grossman and Helpman (1991) this specialisation pattern is assumed as the South is only allowed to imitate.

maturity at the product level by looking at the dynamics in market volume at the global level. Following Audretsch (1987) and Bos et al. (2013), we characterise the life cycle stage of a product using the first and second moment in its global export volume.

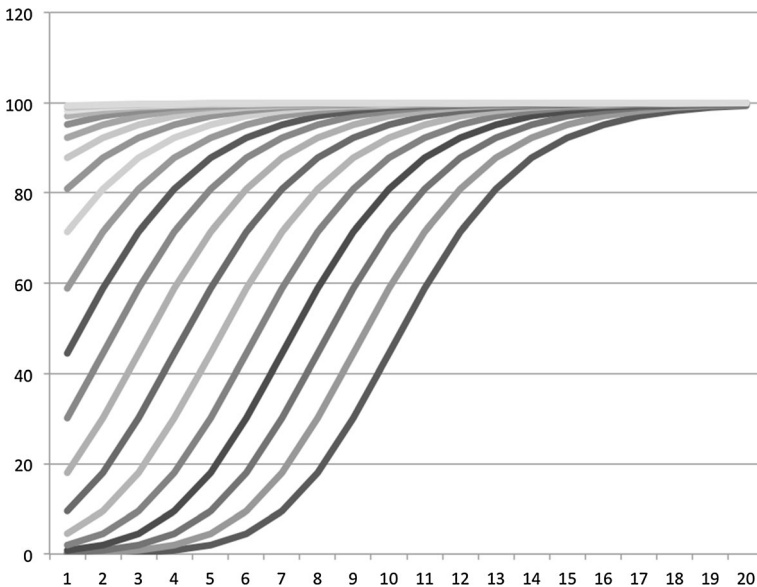
We calculate product maturity for each of the 427 SITC four-digit products over the period 1988–2005 using global-level export data retrieved from the UN-COMTRADE database. The problem with our real trade data is that we do not have the sales volumes for individual products at more disaggregated levels. Instead we have four-digit product classes in which still any number of different products, potentially all in different stages of their respective life cycles, are being added together. However, it is important to note that our product maturity measure captures the *average* life cycle stage of these product classes. More importantly, our measure can correctly identify the rejuvenation of the product class that is the result of replacing a mature with a new product. We demonstrate these features of our measure through a simulation exercise below. The findings confirm that our measure indeed captures the product life cycle stage in data we have generated ourselves and four-digit product is the right product category for the purpose of this paper.

To this end we generated artificial global sales volumes for 20 products and 20 periods using a standard logistic curve we took from Pan and Kohler (2007):

$$Y(t) = A_0 + \frac{A_1}{(1 + A_2e^{(-A_3(t-A_4))})^{\frac{1}{A_2}}} \tag{13}$$

where  $A_0$  is the lower bound and set to 0,  $A_1$  is the upper bound and set to 100,  $A_2$  sets the inflection point where maximum growth occurs and is set to 0, 5,  $A_3$  is the average growth rate, set to 0, 5 and  $A_4$  is the time at which maximum growth is reached and set to 10. The resulting 20 simulated and S-shaped sales paths are shown in Fig. 2.

It is straightforward to see that fitting a second order polynomial to the simulated data in a window of say 5 periods and obtaining the first and second moment of sales (growth and



**Fig. 2** Simulated sales. All series represent a single product. All products were started at different initial levels of sales and simulated for 20 periods

growth in growth) would be sufficient to characterise the product life cycle stage. Suppose we estimate and compute:

$$\ln(Y_t) = \gamma_0 + \gamma_1 t + \gamma_2 t^2 + \varepsilon_t. \quad (14)$$

The exact numerical values are not relevant in this case. If we find a positive coefficient  $\gamma_1$  and negative coefficient,  $\gamma_2$  on the quadratic term the product is to the right of the inflection point and might be called mature. If both  $\gamma$ 's are positive the product must be to the left of the inflection point and might be called early stage. Moreover, taking as our measure of maturity the first derivative of the fitted second order polynomial with respect to time ( $\gamma_1 + 2 * \gamma_2 * t$ ), gives us a continuous measure of maturity, where higher (less negative) values characterise less mature products.

One issue with our real trade data is that we do not have the sales volumes for individual products. Instead we have 4-digit product classes in which still any number of different products at different stages of their respective life cycles are being bundled together. It is clear from Fig. 2 that portfolio's composed of products in different stages of their life cycle can create quite complex sales dynamics, even if we abstract from all kinds of shocks that can affect sales in addition to the product life cycle. Furthermore, by adding new products and dropping mature ones from existing portfolio's, the possibility arises that the maturity of a given portfolio actually *decreases* over time. We can illustrate these cases with our simulated sales data. First we create four portfolio's of products (artificial product classification codes if you will). One portfolio consists of new products (1–5), one of slightly more mature (6–10), the third of even more mature (11–15) and the fourth of products where there is hardly any growth in sales (16–20). Of course our maturity measure should correctly rank them. Given that we have generated the data we can measure the growth and growth in growth of sales precisely and our maturity index becomes:

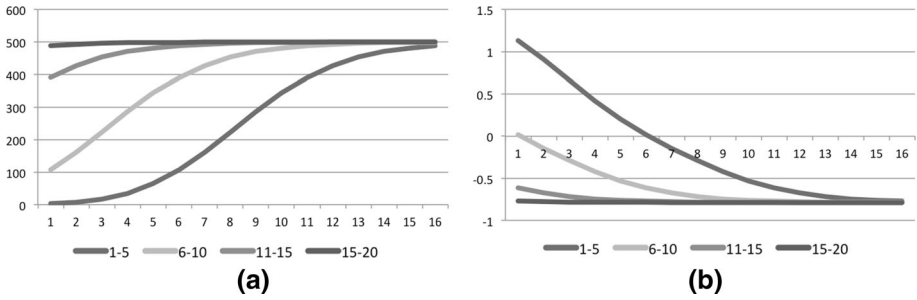
$$d\ln(Y_t)/dt = \gamma_1 + 2 * \gamma_2 * dt \quad (15)$$

where  $dt = 1$ .<sup>13</sup> We then obtain the Fig. 3.

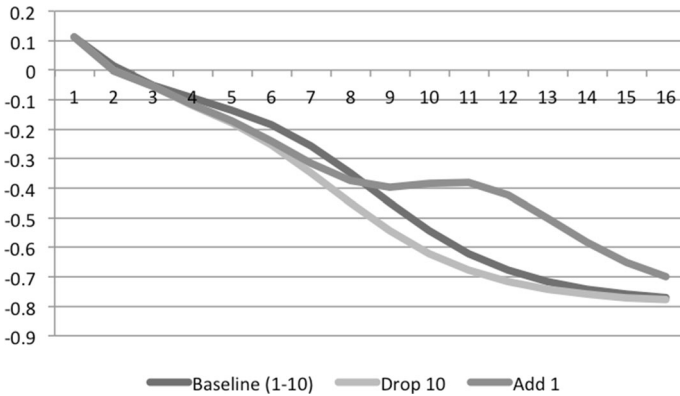
One can see that the composed portfolios still retain the imposed S-shaped sales pattern (left panel) and our maturity measure accurately captures the *average* lifecycle stage of the four portfolios.<sup>14</sup> In Fig. 4 we show the maturity index for a baseline portfolio (1–10) where in period 4 we took out product 10 (the most mature product) in the “drop 10” simulation and added product 1 (the newest product) in the “add 1” simulation. It is clearly visible in this figure that our maturity index picks up the rejuvenation of the portfolio that is the result of replacing a mature with a new product. But it does so only with a lag. We see that adding a very early stage product (in the near horizontal left part of the S-shape) to replace a product around the inflection point where sales growth is maximised (recall this is around year 10 or for product 10 in year 1 by construction) will “fool” our maturity index and cause it to initially drop below the baseline portfolio score. Still, after only a few periods and faster when products exit closer to the horizontal part on the right, our index will quickly show an increase relative to the baseline. In the real trade data it is most unlikely that products will exit the portfolio at the peak of their global market growth, so we do not expect this “fooling”—effect to be a big problem. Moreover, as many more than 10 product varieties are typically in a single

<sup>13</sup> Alternatively one could say we “estimate” the coefficients of a second order polynomial on a two year window, exactly exhausting our degrees of freedom. Of course in our real world data we need and will indeed use a wider time window.

<sup>14</sup> The maturity index is, however, only an ordinal measure of maturity. There is no cardinal interpretation of the values we obtain. The index is equal to sales growth plus two times the growth in growth.



**Fig. 3** Simulated sales and maturity index. **a** Sales, **b** maturity



**Fig. 4** Rejuvenation. Portfolio “Drop 10” contains only 9 products and cannot be directly compared to the other two that have 10 products

4-digit product class, it is unlikely for any single product to have a noticeable impact. Still this figure illustrates that over time, if many new products and product varieties enter an existing product class, our proposed maturity index may actually go up, signifying the portfolio of products in that class becomes less mature over time.

Before we can take our index to the data, however, we need to deal with the fact that some changes in global export sales growth (and growth in growth) do not originate from technology and the individual product life cycle, but rather come from the demand side, affecting all product sales (growth rates) at the same time. To control for the global business cycle we therefore estimate the following equation:

$$\ln(\exp_{it}) = \gamma_0 + \gamma_1 t + \gamma_2 t^2 + \gamma_3 \ln(\exp_t) + \varepsilon_{it} \tag{16}$$

where  $\ln(\exp_{it})$  is the log of global exports of product  $i$  at time  $t$  in constant dollars;  $t$  and  $t^2$  are time (set to 1 at the start of the relevant time window) and time squared, respectively;  $\ln(\exp_t)$  is the log of global total exports of all products;  $\varepsilon$  is the disturbance term. We can then set our measure of maturity,  $M_{it}$ , equal to the effect of an increase in time  $t$  on the log of global exports  $\ln(\exp_{it})$ , controlling for global demand shocks.  $M_{it}$  is thus defined as:

$$M_{it} = \frac{\partial \ln(\exp_{it})}{\partial t} = \gamma_{1i} + 2 \times \gamma_{2i} \times t, t = 1, 2, \dots, 9 \tag{17}$$

where we have taken a 9 year window to estimate the moments of total global exports. Assuming the typical S-shaped pattern of sales over the life cycle we can show that the lower (more negative)  $M_{it}$  is, the more mature a product is. For early stage products both coefficients are typically positive, whereas for more mature products first  $\gamma_{2i}$  and then  $\gamma_{1i}$  will first show up insignificant and then negative in the regression.

We calculated  $M_{it}$  for each of the 427 SITC four-digit products over the period 1988–2005 using global-level export data retrieved from the UN-COMTRADE database.<sup>15</sup> More specifically, we estimate Eq. (16) taking a rolling window of 9 years, namely 1988–1996, 1989–1997, 1990–1998, 1991–1999, 1992–2000, 1993–2001, 1994–2002, 1995–2003, 1996–2004, 1997–2005 setting the first year to 1 to calculate  $M_{it}$  as in Eq. (17) and taking the average of all  $M_{it}$  over the different sub-samples. This implies that only if we estimate different coefficients per window, the corresponding average maturity for that window will change over time. In this way, we allow for maturity to change over time in a non-linear fashion and movements up and down are allowed.<sup>16</sup>

Four important aspects of our measure  $M_{it}$  are worth pointing out at this stage. First, in contrast to a binary measure to classify industries into either “growing” or “declining” as in Audretsch (1987), our measure is continuous.<sup>17</sup> This property permits a sensible ranking of products based on maturity level in the global export market.

Second, our measure is time-varying. In other words, we allow products to move from one stage of the life cycle to the next and back. This latter property may seem undesirable, but in fact there are good reasons not to exclude such dynamics by construction. As we have illustrated above, mature product categories can rejuvenate through the upgrading of existing products and/or the introduction of new product varieties in the same product category. Such rejuvenation could set off a new S-shaped pattern in global sales that we want our measure to pick up. In this respect, our measure also differs from Bos et al. (2013) who evaluates Eq. (17) at the mean of  $t$  for all industries and does not allow for the changes of product maturity over time.

Third, we based our measure on the global exports of a product. Under the assumption that total global exports correlate with total global production and sales, this will reflect the true product life cycle. Our proxy, however, will also carry some exogenous elements that reflect the growth potential of products in the global market place. As we are interested in the composition of countries’ export bundles, however, it seems only fitting we consider the global market for classifying products as mature or early stage.

Finally, we prefer a product specific measure based on global export volumes over the alternative of country level maturity measures as this measure is less prone to endogeneity

<sup>15</sup> For the estimation purpose, we keep products that have at least have 5 observations during 18 years. The average number of observations per product is 16. We drop 180 products that are in the residual categories “X” since the export data on those products are subject to serious measurement problems. These products only account for on average less than 1% of the global export over our sample period.

<sup>16</sup> We also estimated Eq. (16) using all information 1988–2005, evaluating  $M_{it}$  at each point in time  $t = 1 \dots 18$ . That, however, is a very rough approximation of our preferred approach, as it makes maturity linearly dependent on time by construction and does not allow for the estimated slope coefficients to change over time. The pairwise correlation of the maturity measures computed in these ways is 0.23 (significant at 1%), and the Spearman rank-order correlation is 0.38 (where the null hypothesis that both measures are independent is rejected). This suggests some similarity in their ability to rank products by maturity, but correlations are in fact quite low. As the rolling window approach only allows maturity to change over time when the estimated coefficients change we chose the rolling window approach as our preferred measure.

<sup>17</sup> Audretsch (1987) suggests to consider the sign and significance of  $\gamma_{1i}$  and  $\gamma_{2i}$  to classify industries. An industry is classified as growing when either  $\gamma_{2i}$  was positive and statistically significant at the 90% level or  $\gamma_{2i}$  was statistically insignificant, but  $\gamma_{1i}$  was positive and statistically significant.

**Table 1** Descriptive statistics

Code	Name	Number	Share	Maturity Mean	Maturity SD	Maturity 25 percentile	Maturity 50 percentile	Maturity 75 percentile
0	Food	78	0.087	0.017	0.103	-0.031	0.011	0.065
1	Beverages and tobacco	9	0.014	0.043	0.076	-0.009	0.038	0.084
2	Crude materials	73	0.045	-0.060	0.164	-0.132	-0.041	0.023
3	Mineral fuels, lubricants	13	0.086	-0.117	0.513	-0.097	-0.015	0.050
4	Animal and vegetable oils	9	0.005	-0.006	0.171	-0.090	-0.016	0.060
5	Chemicals	32	0.070	0.026	0.086	-0.015	0.026	0.073
6	Manufacture	99	0.156	-0.011	0.107	-0.043	-0.002	0.034
7	Machinery and transport	55	0.321	0.002	0.090	-0.036	0.008	0.051
8	Miscellaneous manufactures	57	0.152	0.039	0.105	-0.006	0.034	0.076
9	Unclassified manufactures	2	0.032	0.007	0.065	-0.006	0.014	0.038

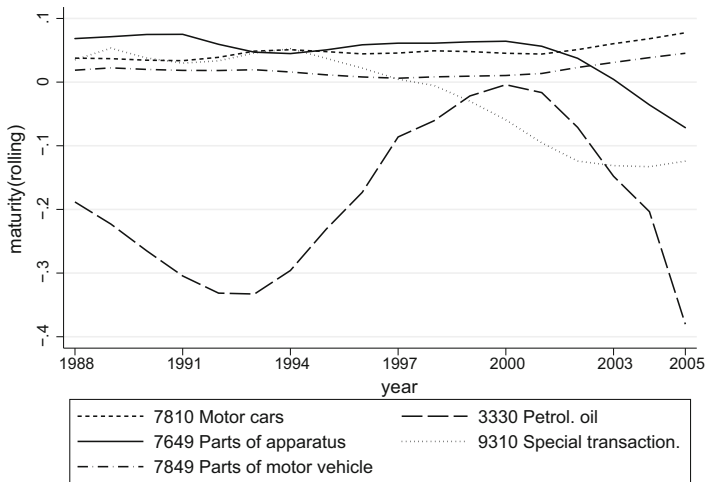
Number denotes the number of four-digit products included in our analysis. Share denotes the percentage of export in the global total export at year 2005

problems in the country level growth regressions that follow.<sup>18</sup> Table 1 provides descriptive statistics on these products, aggregated to the one-digit level.<sup>19</sup> According to Table 1, we find that manufacturing products account for more than 70% of world total exports. The product maturity exhibits significant variations both across and within one digit categories.

A first check on our maturity measure is to simply look at which products actually get classified as mature and young. Ranking products based on their maturity in the global market yields Tables 8 and 9 in the “Appendix”, which show the maturity and ranking of the 50 products with the lowest and highest maturity values at the end of our sample period (i.e., 2005), respectively. The corresponding rank number at the start of the period (i.e., 1988) is also given. The pairwise correlation between maturity 2005 and maturity 1988 is  $-0.021$ , which is not significant at any conventional level. The negative correlation may imply that products classified as mature in 1988 are classified as newer in 2005 and the other way around. The reason is that most products apparently have a (very) negative  $\gamma_2$ , such that they start with a very high  $M_{it}$  (low maturity) and end with a very low value (high maturity), whereas the products with a positive  $\gamma_2$  tend to start from a very low  $\gamma_1$ . This is consistent with a more or less random distribution over the life cycle stages as early stage products would be expected to have low average growth (captured by a low  $\gamma_1$ ) but high growth in growth (captured in a positive  $\gamma_2$ ), whereas mature products have low average

<sup>18</sup> In a similar vein, Bekaert et al. (2007) proposes an exogenous measure of industry-specific growth opportunities by using global average price to earnings (“PE”) ratios in stock markets. They argue that global PE ratios contain information about (global) growth opportunities. Thus, for each country, it permits the construction of an exogenous growth opportunities measure that does not use local price information and is less prone to endogeneity issues.

<sup>19</sup> A list of all products included in our analysis is available upon request.



**Fig. 5** Product maturity—most important products

growth and negative growth in growth. The Spearman rank correlation (0.053), however, shows that the ranking at 1988 and 2005 is independent ( $p$  value is 0.254).

The products at the extremes of the ranking, are perhaps not making a very convincing case at first glance. In particular, the list of least mature products includes several raw materials, ores, basic metals and food products that cannot be considered early stage products. Our measure is clearly sensitive to the 90s resource boom. Rising demand for many internationally traded raw materials, ores and energy resources have caused the trade volumes for those commodities to increase faster than the global trade volume for which we correct. Consequently, the boom in commodities trade is interpreted by our measure as a rejuvenation of these commodities, when of course nothing has happened to the product itself. We will leave these products in for now, exactly because this will bias the estimations against finding the results we are most interested in.<sup>20</sup> Of course we have also excluded these products in robustness tests. The reader should keep in mind, however, that what we measure as maturity is a rough proxy and measurement error is an issue.

The second check is to explore the trend of major products in the global market. Figure 5 shows the maturity of the most important five products (in terms of their size in the global trade) over time. As can be seen from the figure, most manufacturing products are relatively stable and mature. Only petrol oil is moving up and down significantly. Obviously this reflects the peculiarities of global oil markets.

The third check is to explore the volatility of product maturity over time. We want to eliminate those products that exhibit too much volatility over time, e.g. oil. We therefore computed the standard deviation of maturity for each product over the entire sample period. Figure 6 shows the maturity of four products, for which the standard deviation of maturity was above the 99 percentile of the sample. It too suggests that oil products should be treated with caution in our analysis. We keep these “products” in our sample for now, however, to avoid selection bias in our empirical analysis below.

<sup>20</sup> A high degree of specialisation in resources will generally bias the positive effect of exporting new products on economic growth downwards.



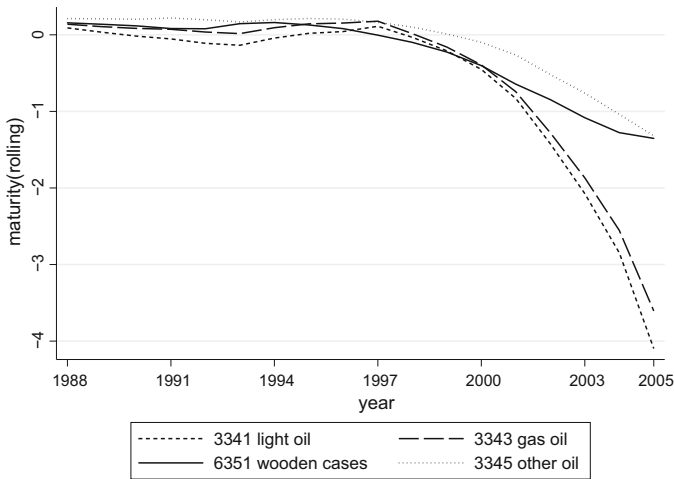


Fig. 6 Product maturity—most volatile products

### 4.2 Measuring the export maturity of countries

The overall maturity associated with a country’s export basket,  $M_{jt}^{All}$ , in turn can now be defined as

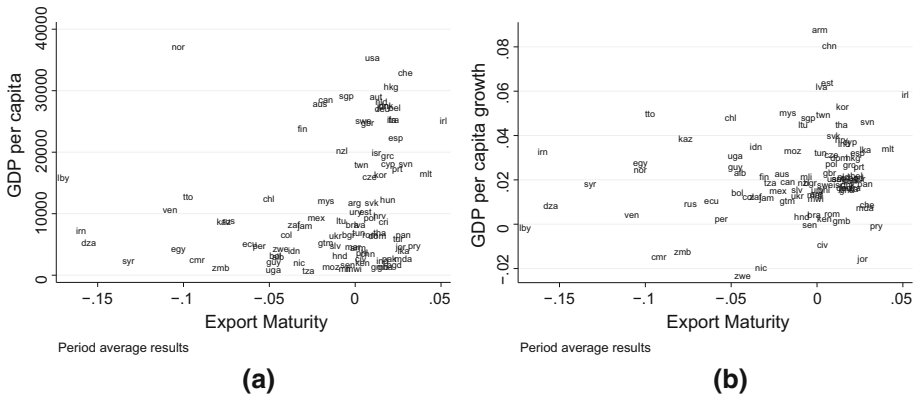
$$M_{jt}^{All} = \sum_i s_{ijt} M_{it} = \sum_i \frac{exp_{ijt}}{exp_{jt}} M_{it} \tag{18}$$

where  $M_{jt}^{All}$  is a weighted average of product maturity  $M_{it}$  (at the global level) across all products for country  $j$  over time  $t$ . The weights are the export shares of these products in country  $j$ ’s total exports.

To get a first impression of our export maturity measure  $M^{All}$ , Fig. 7a shows that on average, a weak positive relationship exists between export maturity and the level of GDP per capita. High income countries appear to have younger export baskets. Figure 7b plots the export maturity measure against the growth rate of GDP per capita. We do not find a strong association, suggesting that the relationship between export maturity and growth might be heterogeneous across countries.

To check the robustness of our results, we also use four other country-level maturity indices by considering sub-samples of products. To account for the peculiarities of commodities, in particular oil, we compute two measures  $M1$  and  $M2$ .  $M1$  excludes the oil-related products, i.e. those for which the first digit product code is 3, whereas  $M2$  includes only the manufacturing products, i.e. those for which the first digit is between 6 and 9.

A handful of studies observe that product quality varies hugely within finely disaggregated products (Schott 2004; Hallak 2006; Khandelwal 2010; Hallak and Schott 2011). To examine whether our results are sensitive to product quality variations across countries, we adopt two other measures  $M3$  and  $M4$  by selecting a sub-sample of products that are more homogenous in quality. Following Sutton and Trefler (2011), we compute  $M3$  using informative products, i.e. products with small quality range across countries. We calculate  $M4$  excluding a category of differentiated products, i.e.,



**Fig. 7** GDP per capita, growth and export maturity. **a** GDP per capita and export maturity. **b** Growth and export maturity

**Table 2** Correlation matrices for the export maturity indices (pooled data)

	$M^{All}$	$M1$	$M2$	$M3$	$M4$
Pairwise correlation (N = 1625)					
$M^{All}$	1.000				
$M1$	0.362*	1.000			
$M2$	0.585*	0.539*	1.000		
$M3$	0.494*	0.317*	0.839*	1.000	
$M4$	0.893*	0.232*	0.464*	0.451*	1.000
Spearman ranking correlation (N = 1625)					
$M^{All}$	1.000				
$M1$	0.472*	1.000			
$M2$	0.802*	0.565*	1.000		
$M3$	0.704*	0.369*	0.837*	1.000	
$M4$	0.853*	0.253*	0.602*	0.591*	1.000

\* Significant at 1%

products without organised exchange markets or reference prices based on a classification developed by Rauch (1999). Table 2 reports pairwise and ranking correlations of all of our five differently constructed measures. We find that these measures are positively and significantly but certainly not perfectly correlated using both pairwise correlations and ranking correlations.

We conclude from these results that our time varying, continuous measure of export maturity reflects something that is correlated with the alternative measures suggested in the literature, is easy to compute based on conventional trade data and is founded in well established empirical regularities over the product life cycle. The proof of the pudding, however, is in the eating. Our measure picks up something of substance if we can show it has explanatory power in a panel growth regression, to which we turn below. For our purpose, we will use  $M^{All}$  in the main analysis and use the other four maturity measures in our robustness analysis.

### 4.3 Other variables and data

Economic growth ( $g$ ), measured as the change of the real GDP per capita is taken from the Penn World Table, version 6.3 (PWT 6.3). To estimate a growth regression we obviously require, in addition to our country level export maturity measure, the standard set of control variables. Levine and Renelt (1992) find that most of the independent variables in standard growth regressions are fragile. Since the effect of export maturity on growth is our primary interest, we minimise the data mining bias for the other variables by closely mimicking the regression in Hausmann et al. (2007). The initial level of GDP per capita  $gdp_0$  (2005 international purchasing power parity (PPP) dollars chain index) is set equal to the start of the different periods.<sup>21</sup> The capital to labor ratio ( $KL$ ) is computed as the physical capital stock divided by the total number of workers. We construct the capital stock ( $K$ ) applying the perpetual inventory method as in Hall and Jones (1999).<sup>22</sup> Human capital ( $HC$ ) is measured as the average years of schooling of the population that is at least 25 years old and is obtained from the Barro and Lee (2010) database on educational attainment.<sup>23</sup> The rule of law index ( $Law$ ), ranging from 0.5 (low institutional quality) to 6 (high institutional quality) is retrieved from the International Country Risk Guide (ICRG) and our de jure trade openness measure ( $Jure$ ) is taken from Wacziarg and Welch (2008). It takes a value of one when a country's trade regime is liberalised, and zero otherwise. In line with Lederman and Maloney (2012), we further add the Hirschman-Herfindahl index as a measure of export concentration, which captures the overall structure of a country's export using the COMTRADE data. They find that export concentration has important implications for understanding the characteristics of a country's export basket in relation to growth. The conditioning variable that we rely on to estimate the latent class model is the stage of economic development for which we proxy by using the level of GDP per capita ( $GDPPC$ ), retrieved from PWT 6.3. Table 3 summarises the definitions, sources and descriptive statistics of country-level variables used in our analysis.

### 4.4 Empirical methodology

A general investigation of the relationship of export maturity and economic growth starts with the following standard growth regression:

$$g_{jt} = \beta_0 + \beta_1 M_{jt}^{All} + \beta' Z_{jt} + \varepsilon_{jt} \quad (19)$$

where  $j$  denotes country and  $t$  denotes time;  $g$  is per capita GDP growth;  $M^{All}$  measures the maturity of a country's export basket; To prevent simultaneity or reverse causality, we take the initial level of the export maturity measure at the beginning of four different time periods (i.e., at 1988, 1993, 1998 and 2003);  $\beta'$  is a  $1 \times n$  parameter vector;  $Z$  is a  $n \times 1$  vector of control variables that contains the usual determinants of economic growth

<sup>21</sup> We split our sample in 4 time periods. The first three periods consists of 5 years, whereas the last one consists of 3 years, namely 1988–1992, 1993–1997, 1998–2002 and 2003–2005. We do so to alleviate some of the endogeneity concerns and to obtain reasonable regime switches, which we will describe later.

<sup>22</sup> We estimate the initial stock of capital,  $K_{t_0}$  as  $\frac{I_{t_0}}{G+\delta}$ , where  $I$  is investment,  $t_0$  refers to the year 1988,  $G$  is the average geometric growth rate of investment. We use the average growth rate over the first 9 years (the first half of our sample) to determine the country-specific average growth rate. The depreciation rate  $\delta$  is assumed to be 6%. The subsequent value of capital stock is computed following  $K_t = (1 - \delta)K_{t-1} + I_t$ .

<sup>23</sup> Since the data is only available at a five-year interval, we use a linear interpolation to fill in missing annual data.

**Table 3** Descriptive statistics—growth regression

	Description	Unit	Source	Mean	Min	Max	SD	Obs
$M^{All}$	Initial export maturity, all products	Index	COMTRADE	-0.017	-0.344	0.123	0.066	1580
M1	Initial export maturity, non-oil products	Index	COMTRADE	-0.002	-0.273	0.124	0.051	1580
M2	Initial export maturity, manufacturing products	Index	COMTRADE	0.008	-0.220	0.119	0.044	1580
M3	Initial export maturity, informative	Index	COMTRADE	-0.015	-0.278	0.143	0.062	1580
M4	Initial export maturity, homogeneous	Index	COMTRADE	-0.047	-0.554	0.113	0.072	1580
$g$	GDP per capita growth	Percentage	PWT 6.3	0.037	-0.455	0.358	0.038	1580
$gdp_0$	Initial GDP per capita	2005 PPP dollars	PWT 6.3	11,414	601	42,490	8168	1580
KL	Capital/labor ratio	2005 PPP dollars	PWT 6.3	122.179	0.615	749.560	133.732	1580
HC	Average year of schooling	Year	BL2010	7.087	0.642	13.086	2.84	1580
Law	Rule of law index	Index	ICRG	3.959	0.5	6	1.468	1580
Jure	De jure openness measure	Index	WW2008	0.801	0	1	0.399	1580
HHI	Trade concentration index	Index	COMTRADE	0.111	0.001	0.843	0.146	1580
GDPPC	GDP per capita	2005 PPP dollars	PWT 6.3	11966	620	44141	10303	1580

BL2005 refers to Barro and Lee (2010); WW2008 refers to Wacziarg and Welch (2008); ICRG refers to International Country Risk Guide

described above, including a country's initial level of GDP per capita ( $gdp_0$ ) to capture beta-convergence, the capital to labour ratio ( $KL$ ), the level of human capital ( $HC$ ) and rule of law index ( $Law$ ), a *de jure* trade openness index ( $Trade$ ) and a trade concentration index ( $HHI$ ); finally,  $\varepsilon$  is an i.i.d. error term.

One major drawback of Eq. (19) is that the relationship between the maturity of exports and economic growth is now assumed to be identical across countries. Therefore, the estimated parameters, e.g.,  $\beta_1$  and  $\beta'$  are common to all countries *by construction*. In practice, it may well be the case that this relationship is not homogeneous and Eq. (19) masks potentially important parameter heterogeneity across countries.

We therefore adopt a flexible modelling framework in which the export maturity-growth relationship is allowed to be heterogeneous across different groups of countries (or growth regimes), depending on the stage of economic development. Two strands of literature motivate our choice of relying on GDP per capita as a proxy of economic development. The

first strand has examined the heterogeneity of growth experience of countries in general and has well established the substantial differences in the determinants of growth between developing and developed countries. These studies (e.g., Durlauf and Johnson 1995; Canova 2004; Papageorgiou 2002) typically use the initial level of GDP per capita as a regime splitting variable to examine multiple growth regimes. However, such an ex ante classification is somewhat arbitrary and subject to debate since the appropriate cut-off point is not always clear. In contrast, our approach endogenizes the cut-off points and is thus much more flexible. The second strand has established a non-linear relationship between export structure (specialised vs. diversified) and economic growth (Imbs and Wacziarg 2003; Aditya and Roy 2007; Cadot et al. 2007; Hesse 2008). These papers typically find that the relationship differs by the development stage of countries as proxied by GDP per capita.

We thus treat the stage of development as a latent variable, and use a latent class model to endogenise the sorting of countries into different growth regimes. To model the latent variable, we use a multinomial logit sorting equation, and include the stage of development, proxied by real GDP per capita, to estimate the likelihood of being in a particular growth regime. Our conditional latent class model consists of a system of two equations: an equation to estimate the maturity-growth nexus for each regime, and a multinomial sorting equation where the regime membership is a function of the development stage, i.e. GDP per capita.

To allow for endogenous sorting into regimes  $k (= 1, \dots, K)$ , we can rewrite Eq. (19) as follows:

$$g_{jt|k} = \beta_k + \beta_{1|k}M_{jt}^{All} + \beta'_k Z_{jt} + \varepsilon_{jt|k} \tag{20}$$

where  $k = 1, \dots, K$  indicates the regime and  $K$  refers to the (endogenous) total number of regimes. Each regime has its own parameter vector  $\beta$ . In other words,  $\beta_0, \beta_1, \beta'$  are allowed to differ across regimes.

To estimate Eq. (20), we must first find the suitable number of  $K$ . As this is not a parameter to be estimated directly from Eq. (20) Greene (2007) suggests a “test-down” strategy to identify the correct number of regimes. A specification with  $K + 1$  regimes is inferior to one with  $K$  regimes if the parameters in any two of the  $K + 1$  classes are equal (statistically indistinguishable). If the true  $K$  is unknown, it is possible to test down from  $K + n$  to  $K$  using a log likelihood ratio test.<sup>24</sup>

Our aim is then to sort each observation  $jt$  into a discrete regime  $k$ . This is done by specifying the contribution of each observation  $jt$  to the likelihood function, conditional on its regime membership. The unconditional likelihood for each observation  $jt$  is obtained as a weighted average of its regime-specific likelihood using the prior probability of being in regime  $k$  as weights. Since we do not observe directly which regime will contain a particular observation  $jt$ , the group membership probability  $\theta_{jt}$  must be estimated. In our conditional latent class framework, we make this probability conditional on GDP per capita ( $GDPPC$ ) and parameterise  $\theta_{jt}$  by means of a multinomial logit model:

$$\theta_{jt} = \frac{\exp(GDPPC_{jt}\theta_k)}{\sum_{k=1}^K \exp(GDPPC_{jt}\theta_k)} \tag{21}$$

where  $\theta_{jt}$  measures the odds of being in regime  $k$ , conditional on  $GDPPC$ . The likelihood for the entire sample, which is the sum of all unconditional likelihood over all  $jt$  resulting

<sup>24</sup> Theoretically, the maximum number of regimes is only restricted by the number of cross-sections, i.e. the number of observations in the data. However, empirically the overspecification problem limits the estimation of a large number of regimes.

from Eqs. (20) and (21), can then be maximised with respect to the parameter vector  $\beta = (\beta_1, \dots, \beta_K)$  and the latent class parameter vector  $\theta = (\theta_1, \dots, \theta_K)$ ,  $\theta_K = 0$  using a conventional maximum likelihood estimator, following Greene (2007). With the parameter vector  $\beta$  and  $\theta$  in hand, a posterior estimate of the regime membership probability for each observation  $jt$ , can be computed using Bayes' theorem. Each observation can then be assigned to the regime with the largest posterior probability.

One distinctive feature of our approach is that we allow countries to switch between regimes over time, following e.g. Bos et al. (2010). We do want to avoid countries close to a switching point, however, from switching back and forth between regimes all the time. We therefore split our sample in four time periods and allow countries to only switch regimes between these four periods. Essentially we pooled together the observations from the time periods and treated observations within these periods as independent draws from the same regime. This implies that one country can be allocated to one particular regime  $k$  in period 1 (1988–1992) and another one in period 2 (1993–1997), but no switches occur within these periods by construction. This adds flexibility into our modelling framework by avoiding the imposed assumption of persistent regime allocation and provides additional insights into regime switches. We can thus study the dynamics of the maturity-growth relationship as countries move along their development path at different speeds.

To summarise our empirical strategy, we employ a conditional latent class model to examine for the possible non-linear relationship between export maturity and growth in  $K$  endogenously determined regimes. The regime membership probabilities are conditional on the stage of economic development.

## 5 Empirical results

### 5.1 Main results

We first determine the number of regimes in our data following the suggestion by Greene (2007). The test results in the top row in Table 4 favour a specification with three regimes over the one with two regimes. We refer to these regimes as developing, emerging and advanced for reasons we will explain later. Moreover, the second row shows that the unconditional latent class model must be rejected in favour of the conditional one. Next, we test whether the parameter estimates differ significantly across regimes by means of Wald tests for joint equality. The results indicate that the equality of all parameters should be rejected at the 1% significance level across regimes. Finally, we test whether the effect of export maturity on growth is significantly different across regimes. The Wald tests here reveal that the effects are jointly significantly different across the three regimes, except between the developing and advanced regime.

From this table we conclude that a three regime, conditional latent class specification is most suitable for our purpose. Then we turn to the effect of the maturity of a country's export portfolio on economic growth across these regimes by looking at the conditional latent class estimation results in Table 5.

First observe in the lower part of the table that the first regime has a low average GDP per capita, the most mature export bundle and the lowest average growth rate. We therefore labeled this regime "developing". The second "emerging" regime has still low but slightly higher average levels of GDP per capita, a considerably higher average growth rate and an intermediate average maturity. The "advanced" regime has a high average level of GDP per capita, moderate growth rates and the lowest average maturity of exports. Note that we

**Table 4** Hypothesis test

Testing	Test	Test statistic	<i>p</i> value	Conclusion
<i>Class fit</i>				
Three-regime conditional	LRT	152.281	0.000	Rejected
Versus two-regime conditional				
Three-regime conditional	LRT	41.263	0.000	Rejected
Versus three regime unconditional				
<i>Equality of all parameters</i>				
Regime developing versus emerging	Wald	97.405	0.000	Rejected
Regime emerging versus advanced	Wald	202.182	0.000	Rejected
Regime developing versus advanced	Wald	28.705	0.000	Rejected
Regime developing, emerging and advanced	Wald	257.298	0.000	Rejected
<i>Equality of export maturity</i>				
Regime developing versus emerging	Wald	9.467	0.002	Rejected
Regime emerging versus advanced	Wald	47.246	0.000	Rejected
Regime developing versus advanced	Wald	0.001	0.975	Not rejected
Regime developing, emerging and advanced	Wald	49.895	0.000	Rejected

LRT likelihood ratio test

have labelled the regimes after the model classified the observations and we based our labels on these average characteristics, not the other way around.

Most interesting from our perspective, however, is the coefficient of export maturity itself. We uncover a negative coefficient which is significant at 1% for the emerging countries' regime, suggesting that a higher maturity index, i.e. a less mature export bundle, is associated with *lower* growth rates. In terms of magnitude, *ceteris paribus*, a one standard-deviation increase in the export maturity index is associated with a decrease of growth rate by 0.84 percentage points. Compared to the average growth rate of 2.8% for the emerging regime, the effect is economically sizeable. This finding strongly contrasts with the advanced countries' regime, where a less mature export mix is associated with *higher* growth rates. *Ceteris paribus*, a one standard-deviation increase in maturity is associated with an increase in the growth rates of 0.63 percentage points, which is considerable comparing to the average growth rate of 2% for the advanced regime. For the developing countries, the relationship is insignificant, implying that the association between the maturity of the export bundle and growth is less clear-cut. Given that many commodities were classified as young products due to the peculiarities of resource and commodities trade in the 90s, the insignificant effect could perhaps be attributed to the fact that developing countries often find themselves exporting some mature manufactures but also commodities.<sup>25</sup>

The conventional determinants in the growth regressions also show interesting differences over the regimes. The developing country regime exhibits beta-convergence (among developing countries). The importance of human capital and the rule of law for developing

<sup>25</sup> The sales volumes of these commodities and resources depend more on the extraction and transport capacity and global demand than production costs. If, as was the case in the 1990s and early 2000s, demand for food, resources and commodities is volatile, then such supply and capacity constraints drive (relative) prices and consequently our measure classifies these non-manufactured products as mature or young as a result of such external market conditions. Possible additional volatility due to speculation in these markets makes this effect even stronger.

**Table 5** Main empirical results

Regime	Developing	Emerging	Advanced
Initial export maturity	0.096 (0.070)	-0.127*** (0.027)	0.095*** (0.018)
Initial GDP per capita	-0.019*** (0.007)	0.018 *** (0.003)	-0.002 (0.002)
Capital/labour ratio	-0.010 (0.009)	-0.010*** (0.002)	-0.001* (0.001)
Human capital	0.007*** (0.002)	0.001 (0.001)	0.001 (0.001)
Rule of law	0.013*** (0.004)	0.005*** (0.002)	0.001 (0.001)
Trade openness	0.019** (0.009)	-0.008** (0.004)	0.006 (0.004)
Trade concentration	0.080*** (0.029)	-0.125*** (0.016)	0.039*** (0.008)
Constant	-0.012 (0.025)	0.014*** (0.007)	0.438** (0.283)
<i>Regime membership probability</i>			
Constant	0.438** (0.283)	0.643*** (0.280)	Reference
GDP per capita	-0.011*** (0.002)	-0.007*** (0.002)	Reference
Prior classification probability	0.191	0.358	0.455
Observations	298	542	740
Mean growth rate of GDP per capita	0.013	0.028	0.02
Mean maturity level	-0.044	-0.014	-0.007
Mean level of GDP per capita	7084	8755	16283

Standard errors in parentheses, \*\*\*  $p < 0.01$ ; \*\*  $p < 0.05$ ; \*  $p < 0.1$

countries are also well established and confirmed in our results. In addition, trade openness and export concentration appear to positively relate to growth. In the emerging regime, countries show strong divergence. The negative relationship between the capital-labor ratio and growth reflects the high returns to capital stock such as infrastructure and reliable power supply in these emerging economies. The accumulation of human capital does not appear significant for growth partially, we would argue, because it is not that important in economies that grow based on exporting mature products. For emerging countries, where inflows of foreign direct investment have been shown to be important, the significance of rule of law is as expected. We also find that export concentration carries a growth penalty for emerging countries and this confirms the finding that a more diversified export structure reduces the vulnerability to adverse terms of trade shocks and is growth promoting. For the advanced economies, we do not find strong evidence of the accumulation of physical and human capital as the driver of growth consistent with economies in their steady states. Also improving openness and rule of law have no significant impact as this regime consists of rather homogeneous countries in openness (actually all are open) and rule of law. However, these countries do seem to perform better with export concentration, in line with the earlier non-linear effect of export diversification on growth found in the literature (Aditya and Roy 2007; Cadot et al. 2007; Hesse 2008; Xuefeng and Yasar 2016). We add to this



literature by showing that diversifying exports into a wider range of *mature* products is probably most effective and relevant for developing and emerging countries, whereas concentrating exports on a range of *new* products has a positive connection to growth for advanced countries.

There are three reasons why we conclude that our latent class specification does not merely sort country-time observations in such a way that these results endogenously emerge. First, the significantly negative coefficient on GDP per capita in the regime membership probability estimation signifies that lower GDP per capita increases the probability of moving from the reference group to the emerging and developing regimes, respectively, where the latter effect is stronger. This implies that countries with high GDP per capita tend to be sorted into the advanced regime, whereas countries with medium GDP per capita sort into the emerging regime and low income countries end up in the developing regime.<sup>26</sup> In an unconditional latent class specification the three regimes might simply emerge because the model fits the data better if one sorts the observations for which a negative, positive and indeterminate effect applies. The fact that GDP per capita has predictive power in the sorting suggests, however, that there is more to these regimes.

Second, in Table 6 we present the regime classifications over time for selected countries. It can be verified that most of the G7 countries are in the advanced growth regime, most of the time, with an occasional switch to the emerging regime and back. The newly industrialised countries in South East Asia, South Africa and Brazil are classified in most periods into the emerging regime and occasionally move between the developing and emerging regimes (with the exception of Singapore which moves from the advanced to developing regime. Financial services, re-exports and port logistics may well have driven this outlier).<sup>27</sup> Interestingly, the exports of mature products by China may constitute an important factor to explain the recent rapid growth and strong convergence of the newly industrialised countries. Our classification is not completely in line with our priors (e.g., Japan classified as emerging in 1988–1992 or Brazil as advanced since 1998), but on the whole the classification looks roughly fine, considering that this classification is in no way based on *ex ante* assumptions and exogenous thresholds or cut-off points.

A final distinctive feature of our model is that a country may change regimes over time. Thus, we can examine the stability of the regime classification by considering regime switches over time. Table 7 presents the regime transition matrix, including the absolute number of regime allocation changes and the frequency between any two time periods.<sup>28</sup> We can see that the diagonal elements carry the largest percentages, as would be expected. However, there are quite some transitions from emerging to advanced and back. Transitions between the advanced and the developing regime are more rare, as is to be expected. Transitions from developing to emerging and back are much more frequent than between developing and advanced. The emerging regime thus seems to be the stepping stone towards the advanced country growth regime.

The occasional switches from developing to advanced and back can also be due, in part, to the disrupting effects of resource and commodities trading, as was argued above. This, however, requires much more detailed analysis of the transition dynamics in our data. A useful first step in that direction would be to redo our analysis without products that can be classified as primary sector products. We feel, however, that at this stage it is useful to leave

<sup>26</sup> Of course we have named these regimes accordingly *ex post* and based on this outcome. The model endogenously identifies three statistically distinct classes/growth regimes.

<sup>27</sup> The full classification of countries in growth regimes is presented in Table 10 in the “Appendix”.

<sup>28</sup> Since we distinguish four time periods, we have three transition matrices. We opt to present the aggregate, unconditional transition probabilities, following Bos et al. (2010).

**Table 6** Classification-selected countries

	Country	1988–1992	1993–1997	1998–2002	2003–2005
G7	Canada	Advanced	Advanced	Advanced	Advanced
	Germany	Advanced	Advanced	Advanced	Advanced
	France	Advanced	Advanced	Advanced	Advanced
	Italy	Advanced	Advanced	Advanced	Advanced
	Japan	Emerging	Advanced	Advanced	Advanced
	United Kingdoms	Advanced	Advanced	Advanced	Advanced
	United States	Advanced	Advanced	Advanced	Advanced
	Brazil	Emerging	Emerging	Advanced	Advanced
	China	Emerging	Developing	Emerging	Emerging
Newly industrialized	Hongkong	Emerging	Advanced	Developing	Emerging
	India	Emerging	Emerging	Emerging	Emerging
	Korea	Developing	Emerging	Developing	Advanced
	Malaysia	Developing	Emerging	Developing	Emerging
	Thailand	Developing	Emerging	Developing	Emerging
	Taiwan	Emerging	Emerging	Advanced	Advanced
	Singapore	Emerging	Emerging	Developing	Emerging
	South Africa	Advanced	Advanced	Advanced	Advanced

**Table 7** Transition matrix

		To		
		A-Developing	B-Emerging	C-Advanced
From	A-Developing	15 (27.27)	30 (54.55)	10 (18.18)
	B-Emerging	16 (17.58)	39 (42.86)	36 (39.56)
	C-Advanced	34 (6.84)	15 (15.38)	42 (77.78)

Numbers denote the transition cases. The transition probability is in the parentheses

these products in the sample. Moreover, one must realise that our classification is endogenously based on the link between growth and trade and therefore sensitive to big shocks in global trade, exchange rates and markets. Our data cover such global trade shocks as the collapse and transition of Russia and the former Eastern Bloc, the Mexican 1994 Peso Crisis, the 1997 Asian Crisis, the Brazilian 1999 Samba Crisis, the collapse of the internet bubble and 9-11. With that in mind the stability of our classification suggests the link between export maturity and growth is indeed different across development stages. Both volatile commodities and global trade stacks the odds against us finding the results we feel are most important to report in this paper. That is, even in the presence of this noise, our maturity measure picks up something of significance, both in the statistical and the economic sense.

If we compare our findings with the existing literature, we can first discuss the any papers that zoom in on specific countries and industries. Chadha (2009) for example demonstrates a positive effect of foreign patent rights on exports for Indian pharmaceutical firms. Our results are in line with their proposition that emerging economies enter the global market at the stage of standardisation and compete on process innovations and cost

advantages, but different in a way that we do not specify the source of cost advantages for the emerging economies, which Chadha (2009) argues could arise from labor, capital or technology. A large number of studies have documented extensively the economic success and industrial achievements of the East Asian economies and an interesting strand of literature takes a closer look at the strategies of the firms in these economies (Hobday 1995; Hobday et al. 2004; Choung et al. 2014). In particular, they show that companies in these countries are showing a strong tendency to go beyond exploiting existing technology and competing on mature markets, rather they compete as frontier players with new and innovative products in the global market.<sup>29</sup> They provide evidence that firms progressed from learning the techniques of manufacturing processes (e.g. strategic partnership, integration in global value chain) and developing competences to eventually engaging in R&D and introducing young and innovative products (Hobday et al. 2004; Pietrobelli and Rabellotti 2011; Choung et al. 2014). Our results corroborate these findings in the literature that emerging economies tend to perform better by exporting mature products but face the challenge of making a transition from copying mature to inventing new products and joining the advanced economies at the frontier. However, these studies do not measure the maturity of the product market directly, nor do they examine the implications of such effects found for the advanced economies. Our paper fills this gap by introducing a novel, macro level measure of product maturity, and assessing the effect of export maturity on country performance instead. With our measure we are thus able to study the relationship between export maturity and growth across a number of countries.

Our results extend and complement recent studies that examine the linkages between the product characteristics of exports and economic growth (Feenstra and Rose 2000; Bensidoun et al. 2002; An and Iyigun 2004; Hausmann et al. 2007; Lee 2011). Table 5 not only shows that export maturity as we have measured it, matters for growth. It also shows that this effect depends on the stage of economic development and is significantly non-linear in the level of GDP per capita. This finding is contrary to the common conclusion that emerges from the literature. In spite of a wide variety of measures, specifications and econometric techniques used, it typically postulates a linear monotonic relationship between specific characteristics of exports and growth. Consistent with the notion that “what you export matters”, however, our findings suggest that the timing of exports in relation to the development process matters as well.

## 5.2 Robustness analyses

We conducted several robustness checks that show that our results are insensitive to the choice of particular maturity measures. First, to account for the peculiarities of commodities, in particular oil, we consider two alternative export maturity measures: *M1* that excludes the oil-related products, and *M2*, which only includes manufacturing products. We report the specification test results in Tables 11 and 12 in the “Appendix”, respectively. Again, these statistical tests indicate that a three-regime conditional latent class model is preferable. The estimation results are shown in Tables 13 and 14 in the “Appendix”, respectively. The non-linear relationship between export maturity and growth over three development stages is found to be rather similar to those reported in Table 5. We observe a significant positive relationship between a higher maturity index and growth for

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<sup>29</sup> Hobday et al. (2004) find that electronic firms in the East Asian countries export a portfolio of products that consists of both low- and high-tech products. This evidence suggest that firms may simultaneously pursue a mixture of imitation-based growth and innovation-based growth as they go through the cycle of catching up and make the transition from latecomer to leader.

the advanced countries' regime and a significant negative one for the emerging countries' regime, albeit the magnitudes are somewhat smaller.

Second, to examine the role of product quality in driving the relationship between maturity and growth, we use two other measures  $M3$  and  $M4$ , following Sutton and Treffer (2011) and Rauch (1999), respectively. Sutton and Treffer (2011) develop a model postulating that a country's wealth and its export mix are simultaneously determined by its capabilities. Thus, economic growth can be achieved either through the shift to a different mix of products or through the improvement in quality/productivity in the existing portfolio of products. Empirically, they demonstrate that the quality range is huge, raising some concerns about the informativeness of Hausmann et al. (2007)'s measure. As a consequence, they illustrate that changes in the export mix may substantially over-predict economic growth for low-income countries. To define which product is informative, they plot the GDP per capital of the richest exporter against the GDP per capita of the poorest exporter for each product in Fig. 8 in the "Appendix". Products that lie in the upper right or bottom left part of the figure, i.e. those with small quality range are considered informative.<sup>30</sup> As can be seen, informative products constitute a small proportion of total products. Based on this definition, we identify 191 informative products (out of 430 in our sample) and calculate  $M3$  using the maturity of these 191 products. Next, we use a classification developed by Rauch (1999) who distinguish products into homogeneous, differentiated and an intermediate categories and calculate  $M4$  by dropping the category of differentiated products. Essentially both  $M3$  and  $M4$  consider a sub-sample of products that are more homogenous in quality, are therefore less prone to quality variations across countries. We expect that the estimated non-linear relationship between maturity and growth to be stronger when using  $M3$  and  $M4$ . The specification tests are shown in Tables 15 and 16 in the "Appendix", respectively. A conditional three-regime latent class model is preferred. The estimation results are presented in Tables 17 and 18, respectively. The results consistently show that the three-regime specification is a very robust feature of our data. The export maturity measure enters with a positive and statistically significant coefficient in the advanced countries' regime, whereas it appears to be significantly negative in the emerging countries' regime. The magnitude is considerably larger for the advanced countries, especially using the maturity measure of informative products  $M3$ , but it is comparable to that found for emerging countries in Table 5.

Overall, our results therefore do not seem to be driven by the inclusion of commodities in our sample or the product quality variations. Arguably, the endogeneity of export maturity also does not pose a serious problem in our analysis for three reasons. First, since we constructed our product-specific maturity measure using the global data, it is less prone to the endogeneity issue than using country-level data. This approach captures some exogenous product characteristics and does not rely on the product information at the country level. Second, we use lagged export maturity, defined as the level at the beginning of each four periods (i.e. 1988, 1993, 1998, 2003) in our estimations, to alleviate the reverse causality problem. And third, the identification of the negative coefficient between export maturity and growth in the emerging regime suggests that reverse causality cannot be an issue. As countries enjoying higher growth are less likely to export mature products that are in the declining stage, we feel that the causality running from export maturity to growth is far more plausible. Therefore we feel confident that the empirical set-up we adopted ensures the validity of our estimation results. We now turn to our conclusions to discuss the significance of our findings.

<sup>30</sup> More precisely, the (ln) minimum GDP per capita of the country that produces this good is smaller than 8.26 and the (ln) maximum GDP per capita is 9.99.

## 6 Conclusions

In this paper, we set out to develop a new measure of product maturity using old knowledge about the product life cycle. A typical product will diffuse in global trade (if at all) approximately following an S-shaped diffusion curve, where total market volume increases fast, then slower and eventually goes into decline. In global markets a product was thus defined as mature when export growth declines. Using this empirical regularity of the product life cycle we developed a continuous maturity measure and showed that our classification of four-digit products in global trade is positively correlated but certainly not equivalent to other classification methods in the literature. As our empirical analysis went on to show, our measure has something sensible and novel to say about countries' growth performance.

We showed in a conditional latent class growth estimation that countries can find themselves in three distinct growth regimes. That is, the vector of parameters differs significantly between three endogenously determined groups of country-time observations in our data set. In addition, we showed that GDP per capita, as a proxy for the level of development of a country, is a good predictor of class membership and our model distinguishes between low, middle and high income level countries. This too is quite similar to classifications used in the literature, but our classification has the added benefit that we do not impose group membership or have to rely on inherently arbitrary cut-off points.

Finally, we showed that our export maturity measure has a non-linear impact on economic growth over the development stages our countries find themselves in. In the low-income *developing* stage the maturity of exports is not significantly related to growth and such traditional variables as capital-labor ratio's and that institutional quality picks up most of the cross-country, within period variation. This implies that for developing countries getting into or out of mature export products is not expected to affect their growth performance in a predictable direction. In part, this may be due to the fact that some resources and commodities were classified as early stage products as a result of the late 1990s resource boom. This would offset the otherwise positive (or negative) impact of manufactured early stage products, but we feel it is more likely we would have found a significant coefficient in either direction if such biases had been strong. For slightly richer *emerging* countries, in contrast, we found a robust and clearly negative relationship between exporting early stage products and growth. They do better exporting mature (manufactured) products and moving into large but globally saturated or declining markets. This gives them the opportunity to grow fast, capturing market share of others. But, in the *advanced* country stage, the sign switches and exporting mature products becomes a drag on growth. The challenge here is clearly to grow fast on mature products but simultaneously preparing for the next stage, in which early stage innovative exports take over as the engine of growth.

This is clearly a huge policy challenge. The existence of distinct growth regimes and sign-switches between them imply that policies aimed to support the penetration of mature markets (e.g. lax intellectual property standards, autocratic control over infrastructures, export subsidies and cheap bank credit) promote growth first, but may put a drag on it in the next stage of development. The advanced industrialised countries are currently still making their transition from an industrial, managed society to an entrepreneurial society (Audretsch and Sanders 2007). The challenge for emerging countries like China, India and Brazil is to design policies that are flexible enough to take the country to the next stage of development and then keep it at the frontier. What policies will pass that test is an empirical matter and left for further research.

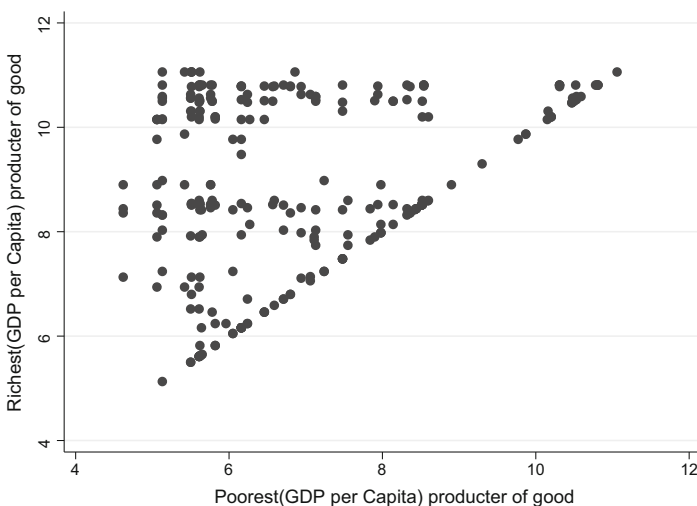
Another clear limitation of our study is the use of trade data on four-digit product classes, which are aggregated over six-, eight- or even ten-digit classes. If the aggregate sale of a four-digit product class grows, our maturity index would then identify it as less mature. This implies that at least the sales of some underlying products within that class grow faster. Having higher levels of disaggregated data would allow us to more precisely separate the less mature products from those mature ones and to more accurately construct the maturity index. As a result, we expect to find stronger positive effects of exporting early-stage products on growth in advanced countries and stronger positive impacts of exporting mature products on growth in emerging countries, respectively. We leave the verification for future research. In all, the use of highly disaggregated trade data opens up new avenues for identifying the precise nature of products, for reducing measurement errors, and therefore improve our understanding of the relationship between international product life cycles, trade and development stages.

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## Appendix

See Fig. 8 and Tables 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18.



**Fig. 8** Informativeness of products

**Table 8** Top 50 least mature products

Name	Percentage of world export	Maturity (year = 2005)	Rank (year = 2005)	Maturity (year = 1988)	Rank (year = 1988)
2112-Calf skins, raw	0.011	0.810	427	-0.139	72
8841-Lenses, prisms and mirrors	0.338	0.749	426	0.009	193
8432-Suits and costumes	0.041	0.724	425	0.073	305
4232-Soya bean oil	0.067	0.709	424	-0.114	88
2234-Linseed	0.005	0.539	423	-0.366	11
0012-Sheep and goats (live)	0.016	0.537	422	0.154	399
0616-Natural honey	0.010	0.512	421	-0.082	108
6760-Rails and railway track construction mater	0.029	0.465	420	0.037	242
4239-Other soft fixed vegetable oils	0.029	0.447	419	-0.021	159
0619-Other sugars	0.035	0.437	418	0.059	282
4313-Fatty acids, acid oils and residues	0.071	0.422	417	-0.015	166
4111-Fats and oils of fish and marine mammals	0.008	0.404	416	-0.016	165
0411-Durum wheat (unmilled)	0.021	0.402	415	-0.118	85
0142-Sausages	0.032	0.388	414	0.140	385
4249-Fixed vegetable oils	0.273	0.388	413	-0.028	154
0565-Vegetables (prepared or preserved)	0.136	0.382	412	0.047	260
0612-Refined sugars	0.107	0.371	411	-0.008	176
3221-Anthracite	0.606	0.361	410	-0.037	139
3231-Briquet and ovoids	0.003	0.356	409	0.153	398
0730-Chocolates	0.278	0.348	408	0.005	188
5417-Medicaments	2.668	0.347	407	0.133	379
2481-Railway or tramway sleepers	0.003	0.343	406	-0.019	161
7188-Engines and motors	0.109	0.329	405	-0.033	147
2815-Iron ore and concentrates (not agglomerated)	0.255	0.328	404	0.008	190
6783-Other tubes and pipes	0.294	0.322	403	-0.049	130
0611-Sugars	0.069	0.318	402	-0.384	9
3354-Petroleum bitumen, petrol and coke	0.134	0.318	401	-0.117	86
6130-Furskins (tanned or dressed)	0.022	0.316	400	-0.193	48
6781-Tubes and pipes	0.013	0.314	399	0.248	424
8928-Printed matter	0.309	0.312	398	0.052	270
8741-Surveying, hydrographic and compasses	0.140	0.305	397	0.057	280

**Table 8** continued

Name	Percentage of world export	Maturity (year = 2005)	Rank (year = 2005)	Maturity (year = 1988)	Rank (year = 1988)
2320-Natural rubber latex	0.127	0.291	396	-0.319	18
2332-Reclaimed rubber	0.004	0.290	395	-0.107	90
2222-Soya beans	0.202	0.284	394	-0.048	132
7211-Agricultural	0.047	0.284	393	-0.131	77
2879-Ores and concentrates	0.162	0.281	392	-0.596	3
0813-Oil-cake and other residues	0.165	0.277	391	-0.037	138
6973-Domestic-type, non-electric heating and cooking	0.100	0.277	390	0.188	415
6611-Quicklime, slaked lime and hydraulic lime	0.006	0.276	389	0.163	405
5416-Glycosides, glands or other organs	0.409	0.264	388	0.154	400
0980-Edible products and preparations	0.391	0.264	387	0.192	416
6359-Manufactured articles of wood	0.181	0.262	386	0.013	198
0460-Meal and flour of wheat and flour	0.032	0.260	385	0.052	269
8483-Fur clothing and articles made of furskins	0.030	0.258	384	-0.090	101
0574-Apples (fresh)	0.050	0.257	383	-0.019	160
0470-Other cereal meals and flours	0.034	0.256	382	-0.055	127
4113-Animal oils, fats and greases	0.020	0.253	381	-0.159	63
2119-Hides and skins	0.011	0.253	380	-0.447	6
5415-Hormones (natural or reproduced)	0.096	0.251	379	0.135	380
8459-Other outer garments	0.452	0.249	378	0.076	311

**Table 9** Top 50 most mature products

Name	Percentage of world export	Maturity (year = 2005)	Rank (year = 2005)	Maturity (year = 1988)	Rank (year = 1988)
3341-Motor spirit and other light oils	0.001	-4.096	1	0.091	333
3343-Gas oils	0.001	-3.605	2	0.139	384
6351-Wooden packing cases, boxes and crates	0.007	-1.352	3	0.157	401



**Table 9** continued

Name	Percentage of world export	Maturity (year = 2005)	Rank (year = 2005)	Maturity (year = 1988)	Rank (year = 1988)
3345-Lubricating petrol and oils	0.067	-1.319	4	0.212	418
6412-Printing paper and writing paper	0.124	-1.101	5	-0.100	95
2235-Castor oil seeds	0.000	-0.668	6	-0.267	32
8710-Optical instruments and apparatus	0.515	-0.643	7	0.069	298
7641-Electric lines	0.572	-0.600	8	-0.007	179
2614-Silk worm cocoons	0.001	-0.546	9	-0.059	124
2683-Fine animal hair (not carded or combed)	0.010	-0.542	10	-0.240	35
2771-Industrial diamonds (sorted)	0.007	-0.491	11	0.520	427
2872-Nickel ores and concentrates	0.069	-0.469	12	-0.290	25
6812-Platinum and other metals of the platinum	0.189	-0.453	13	-0.292	24
0451-Rye (unmilled)	0.003	-0.413	14	-0.106	91
3330-Petrol oils and crude oils	9.535	-0.380	15	-0.188	49
2890-Ores and concentrates of precious metals	0.049	-0.372	16	-0.115	87
2440-Cork, natural, raw and waste	0.003	-0.369	17	-0.030	151
0483-Macaroni, spaghetti and similar products	0.030	-0.294	18	0.177	411
8452-Dresses, skirts, suits etc.	0.044	-0.285	19	0.057	277
8442-Under garments	0.013	-0.284	20	0.238	422
2511-Waste paper (paperboard)	0.066	-0.282	21	-0.417	8
7788-Other electric machinery and equipment	0.983	-0.279	22	0.048	261
2225-Sesame seeds	0.011	-0.259	23	-0.198	46
2517-Chemical wood pulp (soda or sulphate)	0.216	-0.255	24	-0.376	10
2640-Jute and other textile bast fibres	0.001	-0.253	25	-0.085	106
7284-Mach and appliances	1.404	-0.248	26	0.019	211
6831-Nickel and nickel alloys	0.107	-0.245	27	-0.315	20
8813-Photographic and cinematographic apparatus	0.370	-0.243	28	0.013	197

**Table 9** continued

Name	Percentage of world export	Maturity (year = 2005)	Rank (year = 2005)	Maturity (year = 1988)	Rank (year = 1988)
2232-Palm nuts and palm kernels	0.001	-0.242	29	-0.869	2
6863-Zinc and zinc alloys	0.012	-0.237	30	0.053	271
6415-Paper and paperboard	0.240	-0.235	31	-0.130	78
7281-Mechanical tools	0.157	-0.231	32	0.001	184
7754-Shavers and hair clippers with motor	0.029	-0.225	33	-0.008	175
8811-Photographic, cameras, parts and accessories	0.078	-0.224	34	0.062	284
2512-Mechanical wood pulp	0.025	-0.211	35	-0.236	36
7512-Calculating machines and cash registers	2.510	-0.211	36	0.020	215
6542-Fabrics, woven and contain	0.062	-0.194	37	0.073	304
8939-Miscellaneous art	0.760	-0.179	38	0.096	345
2223-Cotton seeds	0.003	-0.176	39	0.298	426
7642-Microphones, loudspeakers and amplifiers	0.153	-0.168	40	0.096	344
6861-Zinc and zinc alloys (unwrought)	0.074	-0.166	41	-0.094	97
7442-Lifting, handling and conveyors	0.491	-0.164	42	-0.009	173
6573-Coated/impregnated textile fabrics	0.129	-0.155	43	0.081	321
8433-Dresses	0.050	-0.148	44	-0.010	172
2516-Chemical wood pulp and dissolving grades	0.017	-0.144	45	-0.277	30
2784-Asbestos	0.004	-0.141	46	-0.101	94
2111-Bovine and equine hides	0.041	-0.141	47	-0.223	41
6822-Copper and copper alloys	0.423	-0.137	48	-0.089	102
2472-Sawlogs and veneer logs	0.063	-0.132	49	-0.068	116
7591-Parts of and accessories	0.161	-0.127	50	0.052	268

**Table 10** Country division (main specification)

Code	Country	1988–1992	1993–1997	1998–2002	2003–2005	Code	Country	1988–1992	1993–1997	1998–2002	2003–2005
<i>Africa</i>											
CIV	Cote d'Ivoire	A	A	A	B	CHN	China	B	A	B	B
CMR	Cameroon	A	B	C	C	BGD	Bangladesh	C	B	C	C
DZA	Algeria	A	A	C	C	HKG	Hong Kong	B	C	A	B
EGY	Egypt	B	C	C	A	IDN	Indonesia	B	B	A	B
GHA	Ghana	C	B	A	C	IND	India	B	B	B	B
GMB	Gambia	B	B	B	C	IRN	Iran	C	A	C	C
KEN	Kenya	B	B	B	C	ISR	Israel	B	C	B	C
LYB	Libya	C	A	A	A	JOR	Jordan	A	B	C	C
MAR	Morocco	B	A	C	C	JPN	Japan	B	C	C	C
MLI	Mali	B	A	B	B	KOR	Korea	A	B	A	C
MOZ	Mozambique	A	A	A	A	LKA	Sri Lanka	C	C	C	A
MWI	Malawi	B	A	B	C	MYS	Malaysia	B	B	A	B
SEN	Senegal	B	B	C	C	PAK	Pakistan	C	C	C	B
TUN	Tunisia	C	C	C	B	PHL	Philippines	B	B	A	B
TZA	Tanzania	A	B	C	C	SGP	Singapore	B	B	A	B
UGA	Uganda	C	A	C	C	SYR	Syria	C	A	B	B
ZAF	South Africa	C	C	C	C	THA	Thailand	A	B	A	B
ZMB	Zambia	B	B	B	C	TWN	Taiwan	B	B	C	C
ZWE	Zimbabwe	A	B	A	A	<i>North America</i>					
<i>Europe</i>											
ALB	Albania	A	A	A	A	CAN	Canada	C	C	C	C
AUT	Austria	C	C	C	C	USA	The United States	C	C	C	C
BEL	Belgium	C	C	C	C	<i>Oceania</i>					
CHE	Switzerland	C	C	C	C	AUS	Australia	C	C	C	C
CYP	Cyprus	B	B	C	C						

Table 10 continued

Code	Country	1988-1992	1993-1997	1998-2002	2003-2005	Code	Country	1988-1992	1993-1997	1998-2002	2003-2005
CZE	Czech Republic	C	C	C	C	NZL	New Zealand	C	C	C	C
DEU	Germany	C	C	C	C						
DNK	Denmark	C	C	C	C						
ESP	Spain	C	C	B	C		<i>South and Central America</i>				
FIN	Finland	A	B	B	C	ARG	Argentina	A	C	A	B
FRA	France	C	C	C	C	BOL	Bolivia	C	C	C	C
GBR	Great Britain	C	C	C	C	BRA	Brazil	A	C	C	C
GRC	Greece	C	C	C	C	CHL	Chile	B	B	C	C
HUN	Hungary	A	C	C	C	COL	Colombia	C	C	C	C
IRL	Ireland	B	B	B	C	CRI	Costa Rica	C	B	C	C
ITA	Italy	C	C	C	C	DOM	Dominican Republic	A	C	A	B
MLT	Malta	B	C	B	C	ECU	Ecuador	B	C	B	C
NLD	Netherlands	C	C	C	C	GTM	Guatemala	C	C	C	C
NOR	Norway	C	B	C	C	GUY	Guyana	A	A	B	B
POL	Poland	A	B	C	C	HND	Honduras	B	B	B	C
PRT	Portugal	B	C	C	B	JAM	Jamaica	B	B	B	B
SVK	Slovakia	B	C	B	C	MEX	Mexico	C	A	C	C
SWE	Sweden	C	C	C	C	NIC	Nicaragua	B	B	C	C
TUR	Turkey	B	A	A	B	PAN	Panama	A	B	C	B
						PER	Peru	B	A	B	C
	<i>Former USSR</i>						PRY	Paraguay	A	B	B
ARM	Armenia			A	A	SLV	El Salvador	B	C	C	C
EST	Estonia	B	B	B	B	TTO	Trinidad and Tobago	C	A	B	B
KAZ	Kazakhstan	A	A	A	A	URY	Uruguay	A	B	A	B
						VEN	Venezuela	A	B	B	A

Table 10 continued

Code	Country	1988–1992	1993–1997	1998–2002	2003–2005	Code	Country	1988–1992	1993–1997	1998–2002	2003–2005
LTU	Lithuania			B	B						
LVA	Latvia			B	B						
HRV	Croatia			C	B						
SVN	Slovenia			C	C						

A-Developing, B-Emerging, C-Advanced

**Table 11** Hypothesis test-non-oil products

Testing	Test	Test statistic	<i>p</i> value	Conclusion
<i>Class fit</i>				
Three-class conditional	LRT	139.085	0.000	Rejected
Versus two-class conditional				
Three-class conditional	LRT	42.011	0.000	Rejected
Versus three-class unconditional				
<i>Equality of export maturity</i>				
Class A versus B	Wald	16.888	0.002	Rejected
Class B versus C	Wald	23.894	0.000	Rejected
Class A versus C	Wald	5.088	0.024	(Not) rejected
Class A, B and C	Wald	30.360	0.000	Rejected
<i>Equality of all parameters</i>				
Class A versus B	Wald	92.072	0.000	Rejected
Class B versus C	Wald	231.775	0.000	Rejected
Class A versus C	Wald	37.710	0.000	Rejected
Class A, B and C	Wald	287.684	0.000	Rejected

*LRT* likelihood ratio test

**Table 12** Hypothesis test-manufacturing products

Testing	Test	Test statistic	<i>p</i> value	Conclusion
<i>Class fit</i>				
Three-class conditional	LRT	139.937	0.000	Rejected
Versus two-class conditional				
Three-class conditional	LRT	42.965	0.000	Rejected
Versus three-class unconditional				
<i>Equality of export maturity</i>				
Class A versus B	Wald	23.940	0.000	Rejected
Class B versus C	Wald	13.105	0.000	Rejected
Class A versus C	Wald	8.450	0.004	Rejected
Class A, B and C	Wald	26.412	0.000	Rejected
<i>Equality of all parameters</i>				
Class A versus B	Wald	111.039	0.000	Rejected
Class B versus C	Wald	253.736	0.000	Rejected
Class A versus C	Wald	51.091	0.000	Rejected
Class A, B and C	Wald	319.959	0.000	Rejected

*LRT* likelihood ratio test

**Table 13** Empirical results-non-oil products

Regime	Developing	Emerging	Advanced
Initial export maturity (non-oil)	0.284***	-0.095***	0.089***
Initial GDP per capita	-0.023***	0.028***	-0.005***
Capital/labor ratio	-0.004	-0.019***	0.000
Human capital	0.007***	0.000	0.001
Rule of law	0.009**	0.003**	0.002***
Trade openness	0.009	-0.005	0.005
Trade concentration	0.044	-0.106***	0.032***
Constant	0.024	-0.062***	0.022***
<i>Regime membership probability</i>			
Constant	0.430	0.519	Reference
GDP per capita	-0.010***	-0.007***	Reference
Observations	317	521	742

\*\*\*  $p < 0.01$ ; \*\*  $p < 0.05$ ; \*  $p < 0.1$

**Table 14** Empirical results-manufacturing products

Regime	Developing	Emerging	Advanced
Initial export maturity (manuf.)	0.266***	-0.086**	0.076***
Initial GDP per capita	-0.019***	0.026***	-0.005***
Capital/labor ratio	-0.004	-0.018***	0.001
Human capital	0.007***	0.000	0.000
Rule of law	0.011***	0.003*	0.003***
Trade openness	0.008	-0.003	0.002
Trade concentration	0.045	-0.099***	0.029***
Constant	0.002	-0.058***	0.021***
<i>Regime membership probability</i>			
Constant	0.677**	0.655**	Reference
GDP per capita	-0.011***	-0.006***	Reference
Observations	362	537	681

\*\*\*  $p < 0.01$ ; \*\*  $p < 0.05$ ; \*  $p < 0.1$

**Table 15** Hypothesis test-Sutton's measure

Testing	Test	Test statistic	$p$ value	Conclusion
<i>Class fit</i>				
Three-class conditional	LRT	134.378	0.000	Rejected
Versus two-class conditional				
Three-class conditional	LRT	40.878	0.000	Rejected
Versus three-class unconditional				
<i>Equality of export maturity</i>				
Class A versus B	Wald	26.122	0.000	Rejected
Class B versus C	Wald	40.938	0.000	Rejected

**Table 15** continued

Testing	Test	Test statistic	<i>p</i> value	Conclusion
Class A versus C	Wald	3.645	0.056	(Not) rejected
Class A, B and C	Wald	46.948	0.000	Rejected
<i>Equality of all parameters</i>				
Class A versus B	Wald	78.489	0.000	Rejected
Class B versus C	Wald	185.099	0.000	Rejected
Class A versus C	Wald	31.502	0.000	Rejected
Class A, B and C	Wald	232.598	0.000	Rejected

LRT likelihood ratio test

**Table 16** Hypothesis test-Rauch's measure

Testing	Test	Test statistic	<i>p</i> value	Conclusion
<i>Class fit</i>				
Three-class conditional	LRT	158.945	0.000	Rejected
Versus two-class conditional				
Three-class conditional	LRT	40.878	0.000	Rejected
Versus three-class unconditional				
<i>Equality of export maturity</i>				
Class A versus B	Wald	9.674	0.001	Rejected
Class B versus C	Wald	65.453	0.000	Rejected
Class A versus C	Wald	0.659	0.417	Not rejected
Class A, B and C	Wald	62.535	0.000	Rejected
<i>Equality of all parameters</i>				
Class A versus B	Wald	96.874	0.000	Rejected
Class B versus C	Wald	248.152	0.000	Rejected
Class A versus C	Wald	25.148	0.000	Rejected
Class A, B and C	Wald	305.133	0.000	Rejected

LRT likelihood ratio test

**Table 17** Empirical results-Sutton's measure

Regime	Developing	Emerging	Advanced
Initial export maturity (Sutton)	0.248***	-0.132***	0.122***
Initial GDP per capita	-0.021***	0.019***	-0.002
Capital/labor ratio	-0.007	-0.009**	-0.002
Human capital	0.007***	0.001	0.001***
Rule of law	0.008**	0.008***	-0.001
Trade openness	0.009	-0.005	0.006**
Trade concentration	0.034	-0.094***	0.033***
Constant	0.031	-0.060***	0.020***
<i>Regime membership probability</i>			
Constant	0.338	0.456	Reference



**Table 17** continued

Regime	Developing	Emerging	Advanced
GDP per capita	-0.010	-0.009	Reference
Observations	321	426	833

\*\*\*  $p < 0.01$ ; \*\*  $p < 0.05$ ; \*  $p < 0.1$

**Table 18** Empirical results-Rauch's measure

Regime	Developing	Emerging	Advanced
Initial export maturity (Rauch)	0.054	-0.128***	0.099***
Initial GDP per capita	-0.017**	0.016***	0.000
Capital/labor ratio	-0.010	-0.009***	-0.003***
Human capital	0.007***	0.001	0.001
Rule of law	0.013***	0.005***	0.001
Trade openness	0.022**	-0.010***	0.009***
Trade concentration	0.072**	-0.126***	0.039***
Constant	-0.019	-0.034	0.009
<i>Regime membership probability</i>			
Constant	0.397	0.588	Reference
GDP per capita	-0.011	-0.007	Reference
Observations	293	528	759

\*\*\*  $p < 0.01$ ; \*\*  $p < 0.05$ ; \*  $p < 0.1$

## References

- Aditya, A., & Roy, S. S., (2007). Export diversification and economic growth: Evidence from cross-country analysis. Mimeo, pp. 1–25.
- Alfo, M., Trovato, G., & Waldmann, R. J. (2008). Testing for country heterogeneity in growth models using a finite mixture approach. *Journal of Applied Econometrics*, 23(4), 487–514.
- An, G., & Iyigun, M. F. (2004). The export skill content, learning by exporting and economic growth. *Economics Letters*, 84(1), 29–34.
- Audretsch, D. B. (1987). An empirical test of the industry life cycle. *Review of World Economics (Weltwirtschaftliches Archiv)*, 123(2), 297–308.
- Audretsch, D. B., & Sanders, M. (2007). Globalization and the rise of the entrepreneurial economy. *CEPR Discussion Papers*, 6247, 1–48.
- Barro, R., Lee, J.-W., (2010). A new data set of educational attainment in the world, 1950–2010. *NBER Working Paper 15902*, pp. 1–49.
- Bekaert, G., Harvey, C. R., Lundblad, C., & Siegel, S. (2007). Global growth opportunities and market integration. *Journal of Finance*, 62(3), 1081–1137.
- Bensidoun, I., Gaulier, G., & Unal-Kesenci, D. (2002). The nature of specialization matters for growth: An empirical investigation. *CEPR Working Paper 13*, pp. 1–30.
- Bos, J., Economidou, C., Koetter, M., & Kolari, J. (2010). Do all countries grow alike? *Journal of Development Economics*, 91(1), 113–127.
- Bos, J. W., Economidou, C., & Sanders, M. W. (2013). Innovation over the industry life-cycle: Evidence from EU manufacturing. *Journal of Economic Behavior & Organization*, 86, 78–91.
- Cadot, O., Carrère, C., & Strauss-Kahn, V. (2007). Export diversification: What's behind the hump? *CEPR Discussion Paper*, 6590, 1–30.
- Canova, F. (2004). Testing for convergence clubs in income per capita: A predictive density approach. *International Economic Review*, 45(1), 49–77.

- Chadha, A. (2009). Product cycles, innovation, and exports: A study of Indian pharmaceuticals. *World Development*, 37(9), 1478–1483.
- Choung, J.-Y., Hwang, H.-R., & Song, W. (2014). Transitions of innovation activities in latecomer countries: An exploratory case study of South Korea. *World Development*, 54(C), 156–167.
- Cline, W. R. (1982). Can the East Asian model of development be generalized? *World Development*, 10(2), 81–90.
- Cline, W. R. (2010). Exports of manufactures and economic growth: The fallacy of composition revisited. In: Spence, M., Leipziger, D. (Eds.), *Globalization and growth: Implication for a post-crisis world*, pp. 195–234.
- Connolly, M. (1999). *North-south technological diffusion: A new case for dynamic gains from trade*. Duke University Department of Economics Working Paper 99-08.
- Dalum, B., Laursen, K., & Verspagen, B. (1999). Does specialization matter for growth? *Industrial and Corporate Change*, 8(2), 267–88.
- de Pineres, S. A. G., & Ferrantino, M. (1997). Export diversification and structural dynamics in the growth process: The case of Chile. *Journal of Development Economics*, 52(2), 375–391.
- Dollar, D. (1986). Product cycle in the North-South trade. *American Economic Review*, 76, 177–190.
- Durlauf, S. N., Johnson, P., & Temple, J. (2005). Growth econometrics. In: Aghion, P., Durlauf, S. (Eds.), *Handbook of economic growth*, 1st edn. Vol. 1, Part A. Elsevier, Chapter 08, pp. 555–677.
- Durlauf, S. N., & Johnson, P. A. (1995). Multiple regimes and cross-country growth behaviour. *Journal of Applied Econometrics*, 10(4), 365–384.
- Feenstra, R. C., & Rose, A. K. (2000). Putting things in order: Trade dynamics and product cycles. *The Review of Economics and Statistics*, 82(3), 369–382.
- Flam, H., & Helpman, E. (1987). Vertical product differentiation and North-South trade. *American Economic Review*, 77, 810–822.
- Giles, J. A., & Williams, C. L. (2000). Export-led growth: A survey of the empirical literature and some non-causality results. Part 2. *Journal of International Trade & Economic Development*, 9(4), 445–470.
- Greene, W. (2007). *LIMDEP, Version 9.0: Reference Guide*. Econometric Software, Inc.
- Grossman, G., & Helpman, E. (1991). Quality ladders and product cycles. *Quarterly Journal of Economics*, 109, 557–586.
- Gylfason, T. (2004). Natural resources and economic growth: From dependence to diversification. *CEPR Discussion Papers*, 4804(4804), 1–34.
- Hall, R. E., & Jones, C. I. (1999). Why do some countries produce so much more output per worker than others? *The Quarterly Journal of Economics*, 114(1), 83–116.
- Hallak, J. C. (2006). Product quality and the direction of trade. *Journal of International Economics*, 68(1), 238–265.
- Hallak, J. C., & Schott, P. K. (2011). Estimating cross-country differences in product quality. *The Quarterly Journal of Economics*, 126(1), 417–474.
- Hausmann, R., & Hidalgo, C. (2011). The network structure of economic output. *Journal of Economic Growth*, 16(4), 309–342.
- Hausmann, R., Hwang, J., & Rodrik, D. (2007). What you export matters. *Journal of Economic Growth*, 12(1), 1–25.
- Herzer, D., & Nowak-Lehmann, F. (2006). What does export diversification do for growth? An econometric analysis. *Applied Economics*, 38(15), 1825–1838.
- Hesse, H. (2008). *Export diversification and economic growth*. The World Bank Commission on Growth and Development Working Paper 21, pp. 1–25.
- Hidalgo, C., & Hausmann, R. (2009). The building blocks of economic complexity. *Proceedings of the National Academy of Science of the United States of America*, 106(26), 10570–10575.
- Hidalgo, C. A., Klinger, B., Barabási, A.-L., & Hausmann, R. (2007). The product space conditions the development of nations. *Science*, 317(5837), 482–487.
- Hirsch, S. (1967). *Location of Industry and International Competitiveness*. Oxford: Oxford University Press.
- Hobday, M. (1995). East Asian latecomer firms: Learning the technology of electronics. *World Development*, 23(7), 1171–1193.
- Hobday, M., Rush, H., & Bessant, J. (2004). Approaching the innovation frontier in Korea: The transition phase to leadership. *Research Policy*, 33(10), 1433–1457.
- Imbs, J., & Wacziarg, R. (2003). Stages of diversification. *The American Economic Review*, 93(1), 63–86.
- Indijkian, R., & Siegel, D. S. (2005). The impact of investment in IT on economic performance: Implications for developing countries. *World Development*, 33(5), 681–700.
- Jarreau, J., & Poncet, S. (2012). Export sophistication and economic growth: Evidence from China. *Journal of Development Economics*, 97(2), 281–292.

- Jensen, R., & Thursby, M. (1986). A strategic approach to the product cycle. *Journal of International Economics*, 21, 269–284.
- Kellman, M., & Landau, D. (1984). The nature of Japan's comparative advantage, 1965–80. *World Development*, 12(4), 433–438.
- Khandelwal, A. (2010). The long and short (of) quality ladders. *Review of Economic Studies*, 77(4), 1450–1476.
- Klepper, S. (1996). Entry, exit, growth, and innovation over the product life cycle. *American Economic Review*, 86(3), 562–83.
- Klinger, B., & Lederman, D. (2006). *Diversification, innovation, and imitation inside the global technological frontier*. The World Bank Policy Research Working Paper Series 3872, pp. 1–24.
- Krugman, P. (1979). A model of innovation, technology transfer, and the world distribution of income. *Journal of Political Economy*, 87(2), 253–266.
- Lai, E. (1995). The product cycle and the world distribution of income: A reformulation. *Journal of International Economics*, 39, 369–382.
- Lederman, D., & Maloney, W. F. (2012). Does what you export matter? In *Search of empirical guidance for industrial policies. No. 9371 in World Bank Publications*. The World Bank.
- Lee, J. (2011). Export specialization and economic growth around the world. *Economic Systems*, 35(1), 45–63.
- Lee, J.-W. (1995). Capital goods imports and long-run growth. *Journal of Development Economics*, 48(1), 91–110.
- Levine, R., & Renelt, D. (1992). A sensitivity analysis of cross-country growth regressions. *American Economic Review*, 82(4), 942–63.
- Lewer, J., & den Berg, H. V. (2003). Does trade composition influence economic growth? Time series evidence for 28 OECD and developing countries. *Journal of International Trade & Economic Development*, 12(1), 39–96.
- Martin, W. (1993). The fallacy of composition and developing country exports of manufactures. *The World Economy*, 16(2), 159–172.
- Moschos, D. (1989). Export expansion, growth and the level of economic development: An empirical analysis. *Journal of Development Economics*, 30, 93–102.
- Mullor-Sebastian, A. (1983). The product life cycle theory: Empirical evidence. *Journal of International Business Studies*, 14, 95–105.
- OECD (2005). *Micro-policies for growth and productivity: Final report*. Technical report, OECD, Paris.
- Owen, A., Videras, J., & Davis, L. (2009). Do all countries follow the same growth process? *Journal of Economic Growth*, 14(4), 265–286.
- Owen, A. L., & Videras, J. (2012). *The quality of growth*. MPRA Paper 38342, University Library of Munich, Germany.
- Paap, R., Franses, P. H., & van Dijk, D. (2005). Does Africa grow slower than Asia, Latin America and the Middle East? Evidence from a new data-based classification method. *Journal of Development Economics*, 77(2), 553–570.
- Pan, H., & Kohler, J. (2007). Technological change in energy systems: Learning curves, logistic curves and input–output coefficients. *Ecological Economics*, 63(4), 749–758.
- Papageorgiou, C. (2002). Trade as a threshold variable for multiple regimes. *Economics Letters*, 77(1), 85–91.
- Pietrobelli, C., & Rabellotti, R. (2011). Global value chains meet innovation systems: Are there learning opportunities for developing countries? *World Development*, 39(7), 1261–1269.
- Ranis, G. (1985). Can the East Asian model of development be generalized? A comment. *World Development*, 13(4), 543–545.
- Rauch, J. E. (1999). Networks versus markets in international trade. *Journal of International Economics*, 48(1), 7–35.
- Redding, S. (2002). Specialization dynamics. *Journal of International Economics*, 58, 299–334.
- Rodriguez, F., & Rodrik, D. (2001). Trade policy and economic growth: A skeptic's guide to the cross-national evidence. *NBER Macroeconomics Annual*, 15, 261–338.
- Sachs, J. D., & Warner, A. (1995). Economic reform and the process of global integration. *Brookings Papers on Economic Activity*, 26(1), 1–118.
- Schneider, P. H. (2005). International trade, economic growth and intellectual property rights: A panel data study of developed and developing countries. *Journal of Development Economics*, 78(2), 529–547.
- Schott, P. K. (2004). Across-product versus within-product specialization in international trade. *The Quarterly Journal of Economics*, 119(2), 646–677.
- Singh, T. (2010). Does international trade cause economic growth? A survey. *The World Economy*, 33(11), 1517–1564.

- Sutton, J., & Trefler, D. (2011). *Deductions from the export basket: Capabilities, wealth and trade*. NBER Working Papers 16834, National Bureau of Economic Research, Inc.
- Temple, J. (1999). The new growth evidence. *Journal of Economic Literature*, 37(1), 112–156.
- Vaio, G. D., & Enflo, K. (2011). Did globalization drive convergence? Identifying cross-country growth regimes in the long run. *European Economic Review*, 55(6), 832–844.
- Vernon, R. (1966). International investment and international trade in the product cycle. *The Quarterly Journal of Economics*, 80(2), 190–207.
- Wacziarg, R., & Welch, K. H. (2008). Trade liberalization and growth: New evidence. *World Bank Economic Review*, 22(2), 187–231.
- Wörz, J. (2005). Skill intensity in foreign trade and economic growth. *Empirica*, 32(1), 117–144.
- Xuefeng, Q., & Yasar, M. (2016). Export market diversification and firm productivity: Evidence from a large developing country. *World Development*, 82(C), 28–47.