International Relocation of Production and Cross-Country Growth

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Abstract

The process of international relocation of production from high to low-income countries is a central feature of economic globalization and a likely key determinant of the dynamics of output and employment across countries over the last decades. This paper's contribution is twofold. First, using very disaggregated trade data, the paper examines the sign and intensity with which each sector has been affected by the international relocation of production between 1995 and 2007. Second, it analyzes how this relocation process has influenced cross-country growth. Countries that were specialized in 1995 in products that, on average, relocated towards low-income (resp. high-income) economies over the following years, exhibited significantly lower (resp. greater) growth over the 1995-2007 period. This impact is quantitatively important and increases with the country's openness to trade.

KEYWORDS: trade; export sophistication; offshoring; growth.

JEL CLASSIFICATION: F14; F43; O47.

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1 Introduction

The process of the international relocation of production from higher to lower-income countries is a central feature of the increase in economic globalization over the last decades. This process is likely to have considerably influenced the dynamics of output and employment across countries. The importance of this phenomenon has motivated numerous studies on specific sectors, countries and regions (e.g., Lall, Albaladejo and Zhang (2004); Sturgeon, Van Biesebroeck and Gereffi (2008); Timmer et al. (2015)). However, to the extent of our knowledge, this phenomenon and its impact has been analyzed neither systematically across all sectors, nor across a large sample of countries for which the relevant data are available. Is the international relocation of production across country income groups intensifying or fading? How important is this phenomenon across the different sectors? What is the growth impact of this process across countries? This paper studies the aggregate dynamics of the international relocation of production between 1995 and 2007, the sign and intensity with which each sector has been affected by the process and the impact of this process on cross-country growth.

The dynamics of the reorganization of production across countries featuring different levels of development can be framed within the *product life-cycle theory* put forward in Vernon (1966). According to this theory, new products are invented and developed in the advanced economies, from which they are initially exported. Then, as the production process becomes increasingly standardized, the less-developed countries become attractive locations for their production because they offer competitive advantages in terms of cost-saving. At this later stage of the product life-cycle, part or all of their production shifts to less developed countries. These dynamics lead to a continuous process of international relocation of production. In recent times, production fragmentation and offshoring have reinforced this process (Feenstra (1998), Hummels, Ishii and Yi (2001), Yi (2003), Koopman, Wang and Wei (2014)). The analysis of the product life-cycle and the nature and limitations of offshoring has been extended in numerous directions (e.g., Krugman (1979), Grossman and Helpman (1991a), Acemoglu et al. (2012), Antràs (2005), Baldwin and Evenett (2015)). Note that although this international relocation of production tends to be contemplated as moving in one direction (away from rich countries and towards low-wage countries), the process is bidirectional and greatly heterogenous across industries. While some products exhibit a strong relocation trend towards low-wage countries, which is likely due to standardization and decreasing requirements of skills and human capital in their production, other products experience an overall relocation trend towards more advanced economies, which is likely to be the result of product innovation and increasing technical sophistication in the sector.

In this paper, we use the average per capita GDP of each product's exporting countries, which is usually interpreted as a measure of product sophistication, as a measure of the stage of the product in its life cycle. We build on the work by Hausmann, Hwang and Rodrik (2007) (henceforth HHR) and develop their framework in order to measure the extent of the international relocation across sectors and to estimate its impact on cross-country growth. HHR associate to each product an index of *sophistication* (called $PRODY$) that is equal to the average per capita GDP of the product's exporting countries. Thus, an increase (reduction) in the $PRODY$ of a good implies a relocation of its production towards more advanced (less developed) countries.

The contribution of this paper is twofold. First, we use the rate of variation of the $PRODYs$ to study the aggregate dynamics of the international relocation of production between 1995 and 2007 as well as the sign and intensity with which each sector has been affected by this process. Rather surprisingly, we find that the relocation process has not intensified over the 1995-2007 period, although there is a great heterogeneity in this respect across sectors. Second, we estimate the impact of the international relocation of production on the countries' economic growth. We find that countries that were specialized in 1995 in products that, on average, experienced a relocation process towards lower-income (respectively, higher-income) economies over the following years, exhibited significantly lower (resp. greater) growth over the 1995-2007 period. The impact of this relocation process is quantitatively very important and increases with the country's openness to trade. The results hold using instrumental variables that control for the potential endogeneity of the export sophistication measures.

The rest of the paper is organized as follows. Section 2 analyzes the dynamics of the relocation process from an aggregate perspective as well as at the sector level. Section 3 studies the effect of the relocation process on cross-country growth. Section 4 concludes.

2 International Relocation of Production (*incomplete*)

2.1 Measuring production relocation

HHR define the $PRODY$ measure of good k's sophistication at period t as:

$$PRODY_k^t = \sum_{j=1}^{J} \frac{RCA_{kj}^t}{\sum_j RCA_{kj}^t} GDPpc_j^t,$$

where RCA_{kj}^t is the revealed comparative advantage of country j in product k at period t, J is the number of countries and $GDPpc_j^t$ is the country j's per-capita GDP. Thus, the $PRODY$ is a weighted average of the exporting countries' GDP per capita, where the weights are given by each country's specialization in the good. In turn, we define the sophistication index of sector s as the weighted average of the 6-digit products' $PRODY$ included in sector s, using the value-shares of each product in each sector as weights:

$$PRODY = \sum_{k \in s} PRODY \frac{\omega_{kW}^t}{\omega_{sW}^t}, \qquad (1)$$

where ω_{kW}^t and ω_{sW}^t are the value-shares of product k and sector s, respectively, in world trade.

In this paper, we interpret the $PRODY$ index as a measure of the stage of a product in its life cycle. Note that if the production of a good moves from rich countries to developing countries, this good's $PRODY$ will decrease. The opposite can also happen: an increase in a good's $PRODY$ indicates that its average exporter is now a richer country. Therefore, we can use the rate of variation in the $PRODY$, $g(prody_k^t) = \ln(PRODY_k^t / PRODY_k^{t-1})$, to measure the international relocation of production of each good.

An increase in the $PRODY$ of a good indicates that the product is moving upwards in the exporters' income ladder. This is the likely consequence of an increase in the intensity of product innovation and technical sophistication of the product, which tends to relocate the product towards higher-income countries. Conversely, a decrease in the $PRODY$ of a good indicates that the production of the good is moving towards lower-income countries, which is the likely consequence of increasing standardization.

Note that all the $PRODYs$ could grow over time as the GDP per capita of most countries increases. Thus, a more accurate indicator of the change of a good's average exporter along the exporters' income ladder is the difference $g\left(prody_k^t\right) - g\left(prody^t\right)$, where $g\left(prody^t\right)$ is the average growth rate of all the $PRODYs$ (i.e., $g(prody^t) = \sum_{k=1}^{K} g(prody_k^t)((\omega_{kW}^t + \omega_{kW}^{t-1})/2))$. Then, the intensity of international production relocation along the exporters' income ladder can be assessed by measuring the dispersion of the $PRODYs$. As a measure of this dispersion, we use the mean absolute deviation (MAD) of the $PRODYs$' growth rates:

$$MAD\left(g\left(prody^t\right)\right) = \sum_{k=1}^{K} \left|g\left(prody_k^t\right) - g\left(prody^t\right)\right| \frac{\omega_{kW}^{t-1} + \omega_{kW}^t}{2}. \qquad (2)$$

The MAD is calculated as a weighted average of the $PRODYs'$ growth rates, where the weights are the share of each product in world trade (we use the average of the weights at the beginning and at the end of the period). A higher dispersion of the $PRODYs$ growth rates reflects a more intense relocation across the exporters' income groups. Similarly, we can measure the intensity of the international relocation within sector s by calculating the MAD of the $PRODY$ growth rates of the goods in that sector as follows:

$$MAD\left(g\left(prody_s^t\right)\right) = \sum_{k\in s} \left|g\left(prody_k^t\right) - g\left(prody_s^t\right)\right| \frac{\omega_{kW}^{t-1} + \omega_{kW}^t}{\omega_{sW}^{t-1} + \omega_{sW}^t}. \qquad (3)$$

2.2 Data

To construct the $PRODY$ indices, we use the data in BACI (Base pour l'Analyse du Commerce International), which is a database provided by CEPII (Centre d'Études Prospectives et d'Informations Internationales)). The original data of BACI come from the United Nations Statistical Division (COMTRADE database), over which an harmonization procedure is applied for reconciling the data reported by the exporting and importing countries in order to generate a single figure consisting of each bilateral flow in FOB values (Gaulier and Zignago, 2010). We use the Harmonized System (HS)-1992 classification, which comprises more than 5,000 goods. Data on GDP per capita, measured in 2005 prices PPP, come from the World Bank's World Development Indicators (WDI). The trade data used for the calculations of the $PRODY$ indices corresponds to a group of 136 countries. This group responds to a consistent sample of the countries offering trade information over all the reference period (1995-2007) and having a population of at least 500,000 inhabitants. As emphasized in HHR (2007), it is essential to use a consistent sample of countries to avoid index changes due to a changing composition of the sample. Moreover, since non-reporting is likely to be correlated with income, constructing $PRODY$ for different countries could introduce serious bias into the index. The $PRODY$s are calculated using average trade data of three years to attenuate the potential distorting effect of atypical values that may arise from unusual exports in a given year. Therefore, we calculate initial $PRODYs$ averaging trade data for 1995-1997 and final $PRODYs$ averaging data for 2005-2007. Our analysis ends in 2007 to avoid the impact of the Great Recession.

We use data at the 6-, 2- and 1-digit level. The 6-digit products and 2-digit industries that we consider exactly correspond to those in the HS92 classification. However, the final list of 6-digit products for which we use their $PRODY$s is reduced to 4,873 products from the original list of 5,200 products in the HS92 classification. This is because we look for a consistent sample of products that were exported every year by at least one country over the whole reference period (i.e., we exclude the products that do not appear in the statistics of world trade in one or more years between 1995 and 2007). These 4,873 products represent the

98.4% of all the world trade during these years. In turn, the 18 sector classification that we consider results from amending the 21 sections in the HS92 classification as follows in order to break into two sectors some sections that are quantitatively very important while merging other sections that encompass a very small share of international trade. Specifically, we split section 6 into pharmaceuticals and the rest of the chemicals; section 15 into iron and steel on the one hand and the rest of metals and its manufactures on the other; section 17 (machinery) into electrical equipment and mechanical appliances; section 17 (transport equipment) into motor vehicles and the rest of transport equipment. Conversely, we group together sections 8, 11 and 12 (leather, textiles and footwear); sections 9 and 10 (wood and paper); sections 13 and 20 (furniture and other manufactures and stones); and sections 3, 14, 19 and 21 (fats and oils, pearls, arms and works of art). We call the last sector *miscellanea*. As a result of this reorganization, we end up with 18 sectors.

2.3 International production relocation over 1995-2007

We now analyze the dynamics of the international relocation of production over the period 1995-2007 using the $PRODYs$ growth rates and the mean absolute deviation (MAD) that we just defined. Figure 1 shows the average growth rates of the $PRODY$s and the growth of the world's GDP per capita and trade. In turn, Figure 2 shows the evolution of the intensity of the international production relocation using the MAD of the $PRODY$ growth rates. Although the analysis in this paper is based on the data and $PRODY$s at the 6-digit level of disaggregation, in Figure 2 we also use $PRODY$s calculated at a lower level of disaggregation using expression (1). The 1-digit lines are obtained after computing the $PRODY$s for the 18 sectors defined in Subsection 2.2., whereas the calculations for the 2-digit and the 6-digit lines use the $PRODY$s of the 96 industries and nearly 5,000 products, respectively, corresponding to the HS-92 classification. Note that the intensity of the relocation process calculated at the 6-digit level more than triples, on average, the intensity at the 2- and 1-digit level. This is due to the heterogenous dynamics of the 6-digit products within each sector (that is increased by production fragmentation), as a result of which a large fraction of the products within a given sector may move in opposite directions along the exporters' income ladder. These within-sector movements that have an opposite sign cancel out when we use data at the sector level to measure international relocation. Thus, using data at the sector level to measure the intensity of the relocation of production can miss most of the phenomenon.

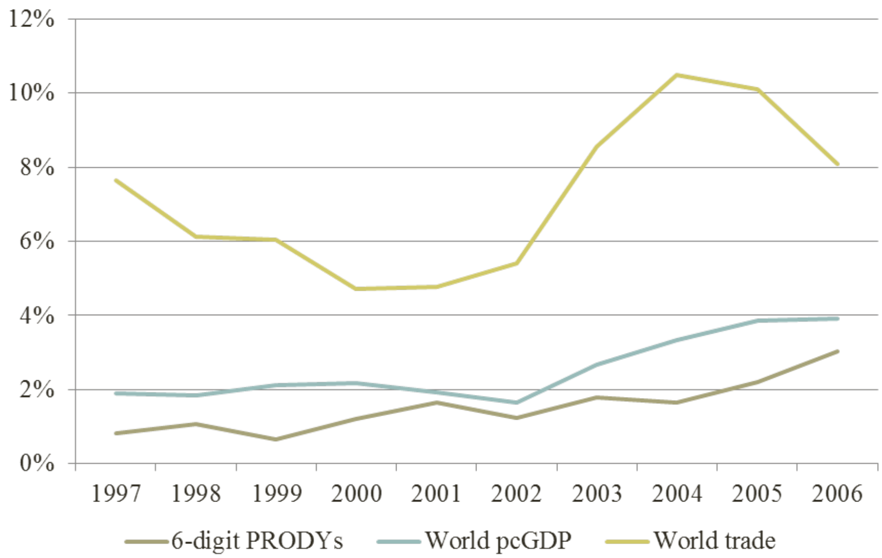

Figure 1: Average growth rates of the $PRODY$s

The intensity of the relocation process appears surprisingly constant over the 1997-2006 period. However, the intensity of relocation and its dynamics over time are very heterogenous across sectors. Table 1 shows the contribution of each sector to the global intensity of production relocation. For sector s, this contribution is calculated as $100 * (\sum_{k \in s} |g(prody_k^t) - g(prody^t)| \frac{\omega_{kW}^{t-1} + \omega_{kW}^t}{2}) / MAD(g(prody^t))$. The highest contributions to the overall international relocation of production come from minerals, machinery and mechanical appliances, textiles, leather and footwear, electrical equipment and chemicals, excluding the pharmaceutical industry. These contributions measure each sector's impact on the changes in the structure of world trade flows across countries' income groups and depend on the weight of the sector in world trade (see col. 2). Therefore, these sectors are not necessarily those with the highest product relocation intensity within sector. This information is in Table 2 together with the sign of the average relocation

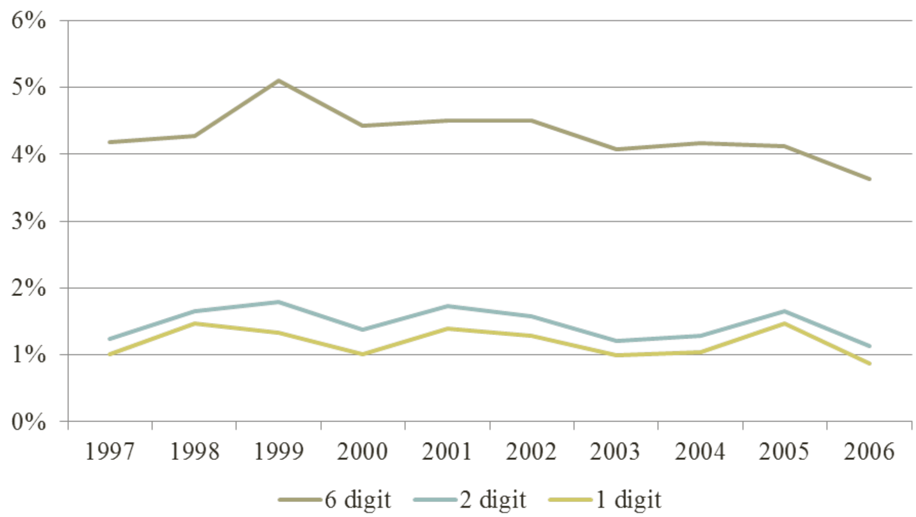

Figure 2: Dynamics of the International Relocation of Production using data at different disaggregation levels
Note: The intensity of international relocation is measured by the MAD of the $PRODY$'s rates of change. The 1-digit line is obtained using data for 18 sectors as explained in Subsection 2.2., whereas the 2-digit and the 6-digit lines correspond to data for the 96 industries and nearly 5,000 products, respectively, in the HS-92 classification.

process in the sector.

Table 2 shows which sectors have undergone the largest upwards and downwards relocations, as measured by the $PRODYs$ growth rates, relative to the average growth rate of all the $PRODYs$. The sectors with the highest growth rates are pharmaceuticals, transport equipment, excluding motor vehicles; wood and paper, iron and manufactures and chemicals. These sectors are moving upwards in the ladder of exporters' income and relocating towards higher-income countries. According to our hypothesis, this relocation process is driven by product innovation or increasing technical sophistication. On the other hand, the sectors that have lagged behind the world average growth rate and are moving downwards in the exporters' income ladder are minerals, textiles, metals and manufactures, motor vehicles and electrical equipment. These sectors are relocating towards lower income countries, driven by increasing standardization of production processes. Some of these sectors are well-known examples of in-

Table 1: Contribution of each sector to the international relocation of production

Sector	Contribution to MAD	Weight in world trade
	1996-2006	1996-2006
Minerals	12.5	11.7
Machinery and mech appliances	11.6	14.8
Textiles, footwear, leather	10.3	7.8
Electrical equipment	9.2	12.3
Chemicals exc. Pharma	7.0	6.5
Metals and manuf. exc. Iron	5.6	3.6
Iron and manufact. thereof	5.3	4.8
Motor vehicles	4.8	9.8
Wood and paper	4.5	3.8
Food, beverage and tobacco	4.2	3.4
Plastics	3.9	4.6
Transport equip. exc. Motor vehic.	3.9	2.4
Pharmaceuticals	3.4	2.0
Miscellanea	3.1	1.4
Animal products	2.9	2.3
Furniture, stone and others	2.8	3.4
Vegetable products	2.5	2.7
Instruments	2.3	2.8
Total economy	100.0	100.0

Note: The contribution of each sector is calculated as
$100 * \sum_{k \in s} \left| g\left(prody_k^t\right) - g\left(prody^t\right) \right| \frac{\omega_{kW}^{t-1} + \omega_{kW}^t}{2} / MAD(g\left(prody^t\right))$.

dustries that have experienced intense offshoring processes (textiles and more recently electrical equipment). Note that among the sectors with high initial $PRODY$ we can find both industries that go up (e.g., pharmaceuticals) and industries that go down (e.g., motor vehicles). Conversely, among the sectors with low initial $PRODYs$, we find industries moving downwards (e.g., textiles), and industries that are moving upwards (e.g., iron and manufactures). In fact, the changes in the $PRODYs$ are only very slightly negatively correlated with the initial $PRODY$ (see Figure 3). The relationship is statistically significant but the estimated elasticity is very low. This means that the current level of a good's sophistication is of no help to predict whether a product will relocate to richer or poorer countries in the following years. Moreover, leaving aside the Miscellanea sector, the highest intensity of the international relocation, as measured by the MAD of the growth rates of the 6-digit $PRODYs$, occurs in Metals and its manufactures excluding iron; textiles, footwear and leather; animal products; food, beverage and tobacco; and transport equipment excluding motor vehicles. However, as long as these sectors do not account for a large share in world trade, their contribution to the transformation of the structure of international trade across income groups is not necessarily the most important as already seen in Table 1.

Table 2: International Relocation of Production by Sector

Sector	Average *PRODY*	*PRODY*s average annual growth 1996-2006	1996-2001	2001-2006	MAD 1996-2001	2001-2006
Motor vehicles	20,311	1.08	0.5	1.4	2.1	1.7
Electrical equipment	18,046	1.17	0.6	1.7	2.3	2.7
Pharmaceuticals	21,966	4.22	4.9	3.5	2.2	0.8
Machinery and mech appl.	20,615	1.33	1.3	1.4	1.9	1.8
Instruments	21,570	1.72	2.1	1.5	2.5	2.4
Furniture, stone and others	14,855	1.66	0.8	2.7	2.7	3.0
Plastics	18,604	1.26	1.6	1.0	2.1	1.8
Vegetable products	9,427	1.31	1.3	1.3	3.4	3.0
Chemicals exc. Pharma	19,609	2.31	2.0	2.5	2.5	2.7
Minerals	11,921	0.91	-0.2	1.9	2.3	1.4
Iron and manufact. thereof	14,750	2.31	1.4	3.1	2.8	2.5
Wood and paper	16,789	2.44	2.3	2.6	2.6	2.2
Transport equip. exc. motor v.	16,368	2.77	2.1	3.5	4.0	1.6
Food, beverage and tobacco	12,183	2.09	2.0	2.2	2.6	3.3
Animal products	14,271	2.23	1.5	3.0	3.3	3.1
Textiles, footwear, leather	8,905	1.06	0.1	1.9	3.1	2.9
Metals and manuf. exc. Iron	15,009	1.07	0.0	1.9	4.9	3.0
Miscellanea	7,771	0.32	-1.5	1.8	4.6	3.6
Total economy		1.5	1.04	1.94		

Note: Each sector's annual $PRODY$ growth is calculated as a weighted average of the 6-digit $PRODY$s' annual growth rates of the products in the sector, using as weights the value share of each product in the sector in 1995-1997 and 2005-2007. The MADs are calculated using expression (3).

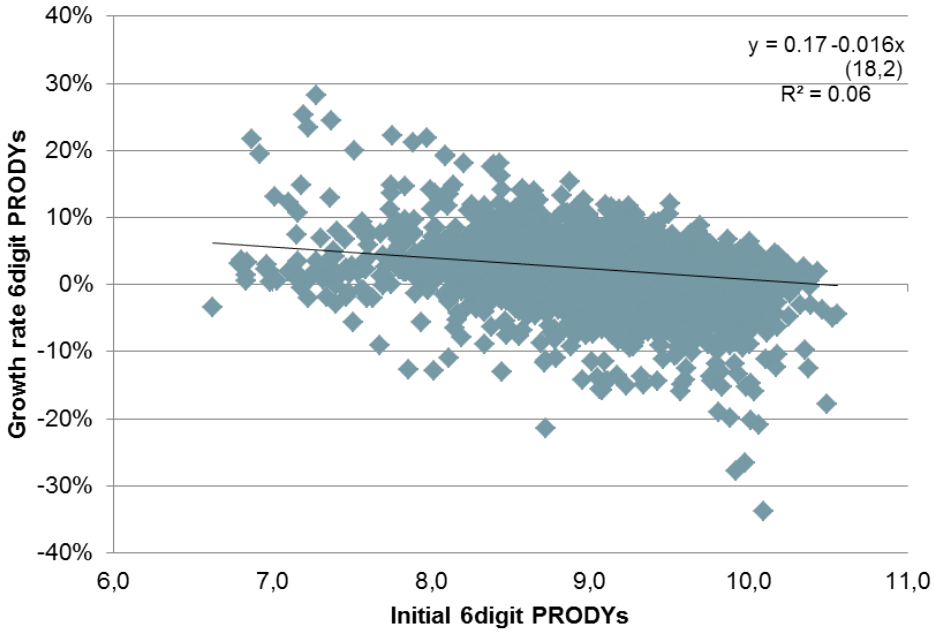

Figure 3: Initial $PRODY$ and its rate of change 1997-2006 (6-digit products)
Note: The coefficients in the box are the result of estimating the expression: $g(prody_k^t) = \beta_0 + \beta_1 ln(PRODY_k^{t-1}) + u$

3 Production Relocation and Growth

3.1 Informal theoretical framework

How does the international relocation of production affect cross-country growth? In the previous section, we observed it is fairly unpredictable the direction and intensity with which the production of each good will move along the ladder of exporting countries in the future. We can find about as many 6-digit products with high $PRODY$s moving up than moving down. The same happens if we examine 6-digit products with low $PRODY$s. As long as the production of each good involves product-specific knowledge and skills, those countries initially specialized in the goods that move up in the exporters' income ladder will more likely increase their growth because their endowments of product-specific knowledge and skills are increasing their value. The opposite will be true for countries initially specialized in the goods that move down.

Producing goods experiencing intense innovation requires a combination of general knowledge and skills (which are abundant in rich countries) and product-specific knowledge and skills (which are abundant in current exporters of the product). In the case of product innovations in an industry, the value of the skills and knowledge used in the production of these goods increases, as long as it is easier for countries with these production factors to start producing the new varieties or use the new methods. Moreover, world demand is likely to increase while world supply lags behind. Thus, the production of the new varieties is temporarily more profitable. On the other hand, if the production of a good experiences increasing standardization, the value of that product-specific knowledge and skills decreases because these products can be be produced with lower human capital. Moreover, the world supply of these products is likely to expand while their prices decrease. Therefore, countries that were specialized in the products experiencing a wave of innovation will be better off and will grow faster; on the other hand, countries that were specialized in products experiencing intense standardization will be negatively affected and will grow slower.

3.2 Measuring the impact on cross-country growth

The relocation process described in Section 2 is likely to have had a different impact across countries depending on the countries' initial specialization. To measure the average sophistication of each country's exports and how international relocation affected its initial specialization, we build again on HHR (2007). HHR define the $EXPY$ index of a country's export sophistication as a weighted average of its exports' $PRODY$s, as follows:

$$EXPY_j^0 = \sum_k PRODY_k^T \omega_{kj}^0;$$

where the weights, ω_{kj}, are the value shares of the products in country's total exports; 0 is the initial year of the period being considered and T is the final year.[1] Note that the $EXPY$ as defined by HHR puts together data from two different periods: on the one hand, the information on specialization ω_{kj}^0 refers to the initial period, while, on the other hand, the $PRODY$s refer to the end of the period (T). In our analysis, we define a *pure* initial $EXPY$, denoted by $IEXPY_j^0$, which is calculated using the data for the initial period for both specialization and the $PRODY$s:

$$IEXPY_j^0 = \sum_k PRODY_k^0 \omega_{kj}^0;$$

where the weights, ω_{kj}^0, are the value shares of the products in country's total exports at the beginning of the period and $PRODY_k^0$ captures the sophistication of products at the beginning of the period. Then, we use the ratio between the HHR's $EXPY$ and the $IEXPY$ (which measures the exogenous change in a country's export sophistication due to product relocation) to capture the impact of the international production relocation on country j:

$$IIPR_j = \frac{EXPY_j^0}{IEXPY_j^0} = \frac{\sum_k PRODY_k^T \omega_{kj}^0}{\sum_k PRODY_k^0 \omega_{kj}^0}. \tag{4}$$

Note that the difference between the two $EXPYs$ is the change in product's sophistication due to international production relocation. A higher value of the ratio reflects an increase in a country's export sophistication due to product relocation towards higher income countries; a lower value of the ratio is a sign of decreasing export sophistication due to product relocation towards lower income countries. Thus, our approach accounts to a simple decomposition of the HHR's $EXPY$ index into two components:

$$\ln(EXPY_j^0) = \ln(IEXPY_j^0) + \ln(EXPY_j^0/IEXPY_j^0). \tag{5}$$

This decomposition is the basis of the econometric specification that follows.

[1] HHR constructed the $PRODY$ measures using data for the 1999-2001. The $PRODYs$ were then used to construct $EXPY$ measures for all the countries reporting trade data during the period from 1992 to 2003. They then used income information for 1999-2001 to assess whether countries with higher $EXPY$ grew faster over the 1992- 2003 period.

3.3 Econometric procedure

This section turns to the econometric analysis on the relationship between initial export sophistication, product relocation and economic growth. Our main specification is the following neoclassical regression, where GDP per capita growth is regressed on $IEXPY$ and the ratio $(EXPY/IEXPY)$ besides initial per-capita GDP and a vector of controls X_j^0 that include human capital and rule of law:

$$\begin{aligned} \frac{1}{T}\ln\frac{y_j^T}{y_j^0} &= \beta_0 + \beta_1 \ln y_j^0 + \beta_2 \ln(IEXPY_j^0) + \beta_3 \ln\left(\frac{EXPY_j^0}{IEXPY_j^0}\right) \\ &+ \beta_4 X_j^0 + u_j \end{aligned} \tag{6}$$

where u_j is the error term.

We estimate several variations of the preceding equation by OLS as well as 2SLS, using instrumental variables, to deal with the potential problem of circularity that arises from the use of the $PRODY$ and $EXPY$ indices. Note that the $PRODYs$ are a weighted average of exporting countries' GDP per capita that are used to construct the $EXPY$ measures of export sophistication, which in turn are used to explain the country's per capita income at the end of the period. To break this circularity, we calculate specific $PRODYs$ for each country that are constructed excluding all the data relative to the country (specifically, we exclude the information on the country's exports and GDP per capita). More precisely, the country j's specific $PRODY$ for good k is defined as:

$$CSPRODY_{k,-j}^t = \sum_{i \neq j} \frac{RCA_{ki-j}^t}{\sum_{i \neq j} RCA_{ki-j}^t} GDPpc_i^t,$$

where RCA_{ki-j}^t is the country i's revealed comparative advantage in good k calculated by excluding country j's exports from world trade. Thus, this index reflects the level of development of the countries other than j producing and exporting product k. We then use these country specific $PRODY$s to construct the instruments for the $IEXPY$s and $EXPY$s, which we denote as $SPIEXPY$

and $SPEXPY$, respectively:

$$SPIEXPY_j^0 = \sum_k CSPRODY_{k-j}^0 \omega_{kj}^0,$$

$$SPEXPY_j^0 = \sum_k CSPRODY_{k-j}^0 \omega_{kj}^T.$$

The use of these measures directly or as instruments in the econometric analysis will eliminate potential problems of circularity.

3.4 Data and Descriptive statistics

The initial building block of the database used in this section are the $PRODY$s calculated in the previous sections and the 6-digit goods' shares in each country's exports from BACI. Human capital is obtained from Barro and Lee database (version 1.3, 2013), and it is proxied by the percentage of population over 25 years with the secondary education complete. As a measure of institutional quality we use *rule of law*, which is obtained from the database World Governance Indicators of the World Bank. When human capital is considered, the sample of 136 countries used to construct the $PRODYs$ is reduced to 118 countries. Moreover, we check potential outliers by identifying the countries whose growth rates in the main variables ($EXPY$ indices or GDP per capita growth) deviate from the sample mean more than three times the sample standard deviation. This filter selects seven counties (Burundi, Central African Republic, Liberia, Sierra Leona, Niger, Mali and Rwanda), all of which had undergone civil wars or ethnic conflicts during the period of interest. We excluded these countries from the sample as their economic performance is unlikely to be explained by economic fundamentals and including them into the analysis may distort the results. This reduced the sample to 111 countries.[2]

Figure 4 shows a scatterplot of initial GDP per capita against the ratio capturing the relocation impact ($EXPY/IEXPY$). There is no correlation between the initial income level and the change in countries' export sophistication due to relocation (the correlation coefficient is 0.15). Thus, at first sight, there was not a

[2]The list of countries can be found in Table A1 in the appendix.

particular concentration of winners or losers of the international production relocation undergone over the 1995-2007 period among the rich or the poor countries. Figure 5 shows the correlation between GDPpc growth and $IEXPY$ (which is 0.08), whereas Figure 6 reflects the positive correlation between the international relocation ratio ($EXPY/IEXPY$) and GDP per capita growth (the correlation coefficient is 0.45).

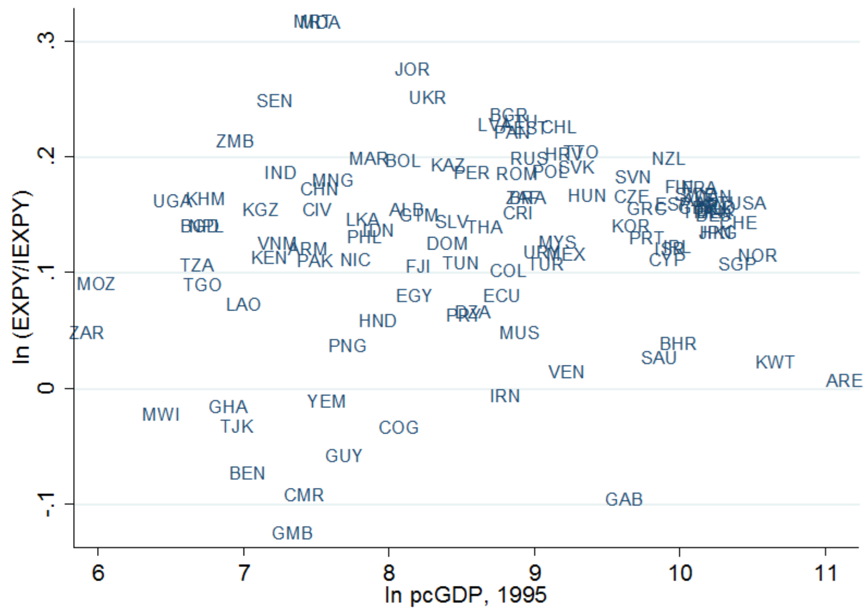

Figure 4: Initial GDP per capita and Impact of International Production Relocation as measured by the ratio $EXPY/IEXPY$

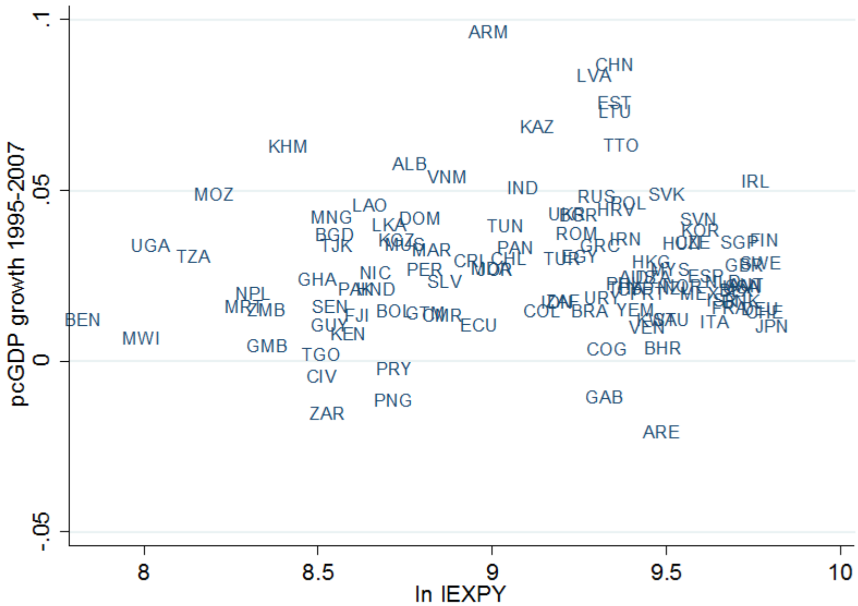

Figure 5: Countries' Initial Export Sophistication ($IEXPY$) and Growth

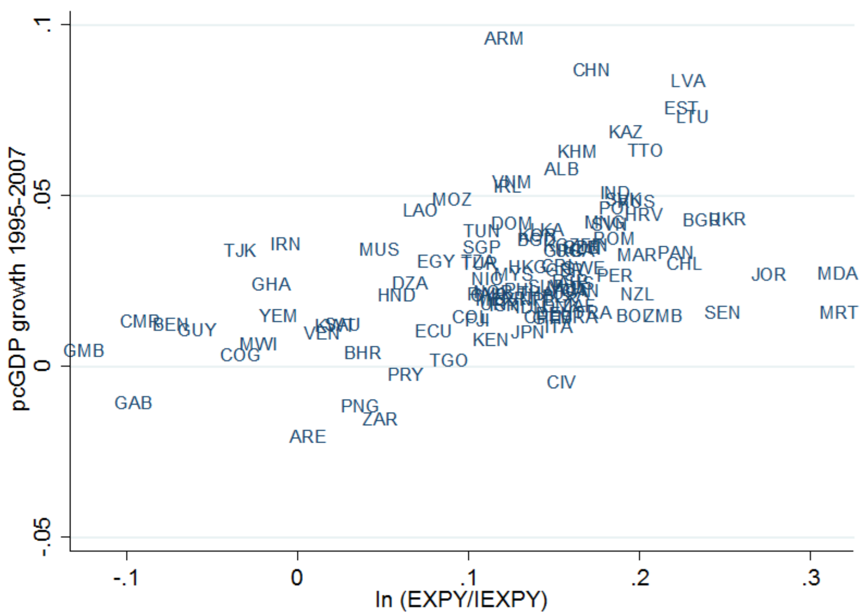

Figure 6: Impact of International Production Relocation (as measured by the $EXPY/IEXPY$ ratio) and Growth

3.5 Main Results

OLS

Table 3 shows the results of cross-country growth regressions over the period 1995-2007. The first column replicates the baseline specification in HHR (2007) and confirms their results with our sample, which contains a larger number of countries. The $EXPY$ measure of export sophistication, initial per capita GDP and human capital have the expected signs and are significant at the 1-percent. The coefficient for the rule of law index is also positive and significant at the 10-percent level. The following specifications in Table 3 substitute the $EXPY$ variable for the two terms of our decomposition: the $IEXPY$ measure of export sophistication and the ratio $EXPY/IEXPY$, which is our measure for the impact on each country of the international relocation of production. We focus on the results in column 4, which correspond to our full specification as written in expression (6). We find that a positive coefficient for the ratio $EXPY/IEXPY$ that is statistically significant at the 1% level. Thus, countries that were specialized at the beginning of the period in product categories showing a relocation process towards low-wage (advanced) economies over the following 1995-2007 period, exhibited significantly lower (greater) growth over that period. The estimated impact is quantitatively very important. Using the coefficient in column 4, which corresponds to our preferred specification, an increase in $\ln(EXPY/IEXPY)$ of the size of one standard deviation (i.e., 0.083) implies an increase in the annual growth rate of 0.77 percentage points. Similarly, taking a country from the 1st quartile to the 3rd quartile along the distribution of the ratio$(EXPY/IEXPY)$ implies an increase in the annual rate of growth of 0.66 percentage points. The coefficient for the $IEXPY$ measure of initial export sophistication is also positive and statistically significant at the 1% level. The initial GDP per capita and the measure of human capital also have the expected signs in all the regressions and are statistically significant. The partial correlation plots in Figure 7 and 8 show that both $IEXPY$ and the ratio $(EXPY/IEXPY)$ play an independent effect on growth and that the results are not due to outliers.

Table 3: Cross-country regressions, 1995-2007. OLS regressions

	Dependent variable: Growth rate of GDP per capita			
	(1)	(2)	(3)	(4)
log initial GDP pc	-0.0176***	-0.0166***	-0.00521**	-0.0129***
	(0.00389)	(0.00457)	(0.00248)	(0.00448)
log EXPY	0.0311***			
	(0.00690)			
log human capital	0.00633***	0.00709***	0.00554**	0.00527**
	(0.00218)	(0.00230)	(0.00263)	(0.00229)
Rule of law	0.00388*	0.00485*	0.000447	0.00143
	(0.00231)	(0.00254)	(0.00211)	(0.00217)
log IEXPY		0.0264***		0.0214***
		(0.00835)		(0.00807)
log EXPY/IEXPY			0.103***	0.0924***
			(0.0217)	(0.0211)
Constant	-0.0956**	-0.0562	0.0706***	-0.0571
	(0.0407)	(0.0461)	(0.0256)	(0.0427)
Observations	111	111	111	111
R^2	0.271	0.208	0.272	0.329

Notes: Dependent variable is the average growth rate of GDP per capita over the period 1995-2007. All variables are in natural logs except rule of law. The number of observations is the same as the number of exporting countries. The estimation method is OLS. Robust standard errors in parentheses. Significance levels: *** 10-percent, ** 5-percent, * 1-percent.

Figure 7: Partial correlation plot

Note: The vertical axis measures $\frac{1}{T}\ln\frac{y_j^T}{y_j^0} - (\beta_0 + \beta_1 \ln y_j^0 + \beta_2 \ln(EXPY/IEXPY_j^0) + \beta_3 X_j^0)$ with the coefficient estimates taken from Table 3, column (4). The horizontal axis measures the value of log $IEXPY$.

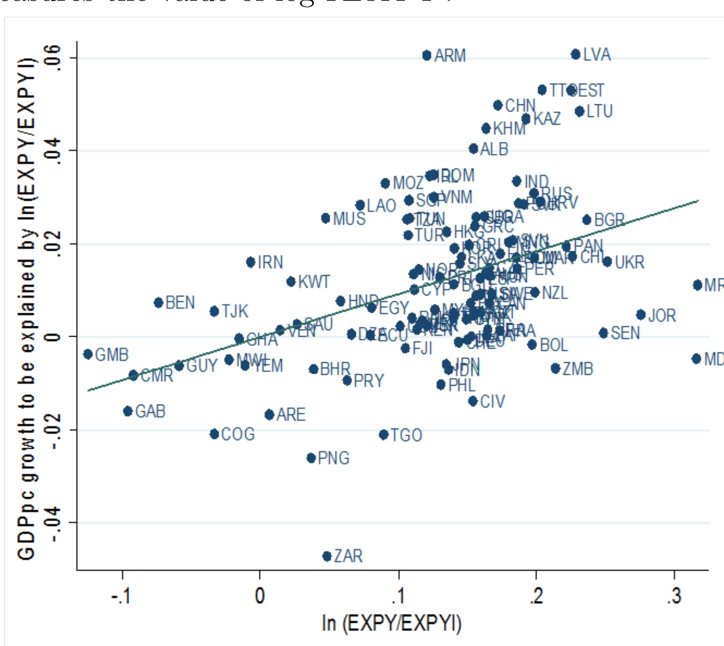

Figure 8: Partial correlation plot

Note:The vertical axis measures $\frac{1}{T}\ln\frac{y_j^T}{y_j^0} - (\beta_0 + \beta_1 \ln y_j^0 + \beta_2 \ln(IEXPY_j^0) + \beta_3 X_j^0)$ with the coefficient estimates taken from Table 3, column (4). The horizontal axis measures the value of log $EXPY/IEXPY$.

IV Estimations

Table 4 summarizes the results using instrumental variables. Specifically, we instrument $IEXPY$ with $SPIEXPY$ and $EXPY/IEXPY$ with $SPEXPY/SPIEXPY$. The measures of export sophistication based on country-specific$PRODYs$ that exclude each country's information have a very high predicting power for the conventional $EXPY$s, as suggested by the value of the F-statistics in the first-stage regressions, which indicate that the instruments are jointly significant in the first stage. We then estimate the same equations as in Table 3 using now two-stage least squares. The estimated coefficients using IV are only slightly smaller and their signs and statistical significance remain unaffected except for the measure of initial export sophistication $IEXPY$ in column 4, which is now significant at the 5-percent level instead of at the 1-percent in OLS. Hence, the results hold when using instrumental variables that control for the potential circularity of the measures of export sophistication and international production relocation.

Table 4: Cross-country regressions. IV regressions

	Dependent variable: Growth rate of GDP per capita			
	(1)	(2)	(3)	(4)
log initial GDP pc	-0.0162***	-0.0161***	-0.00569**	-0.0125***
	(0.00383)	(0.00448)	(0.00257)	(0.00467)
log EXPY	0.0269***			
	(0.00673)			
log human capital	0.00651***	0.00712***	0.00604**	0.00579**
	(0.00215)	(0.00225)	(0.00267)	(0.00234)
Rule of law	0.00391*	0.00480*	0.00129	0.00214
	(0.00226)	(0.00249)	(0.00230)	(0.00231)
log IEXPY		0.0250***		0.0189**
		(0.00814)		(0.00823)
log EXPY/IEXPY			0.0789***	0.0705***
			(0.0229)	(0.0217)
Constant	-0.0685*	-0.0472	0.0788***	-0.0342
	(0.0394)	(0.0446)	(0.0269)	(0.0415)
Observations	111	111	111	111
R^2	0.268	0.208	0.263	0.321
F-statistic	1828,42	1580,69	83,39	1266,09
				69,92

Notes: Dependent variable is the average growth rate of GDP per capita over the period 1995-2007. All variables are in natural logs except rule of law. The number of observations is the same as the number of exporting countries. The estimation method is two-stage least squares. The instruments used are $SPEXPY$: $SPEXPY$, $SPIEXPY$ and $SPEXPY/SPIEXPY$ are used as an instrument for $EXPY$, $IEXPY$ and $EXPY/IEXPY$ respectively (col. (1), (2) and (3)); $SPIEXPY$ and $SPEXPY/SPIEXPY$ are used as instruments in col. 4. The F-tests indicate that instruments are jointly significant in the first stage. Robust standard errors in parentheses. Significance levels: *** 10-percent, ** 5-percent, * 1-percent.

3.6 Export openness and the impact of relocation

International specialization should affect GDP growth only to the extent that exports represent a significant share of the country's GDP. Thus, we now analyze whether the impact of the international production relocation depends on each country's openness to international trade. Specifically, we include a measure of export intensity to the previous specifications, independently as well as interacted with both initial export sophistication $IEXPY$ and the ratio $EXPY/IEXPY$. Thus, the new specification is:

$$
\begin{aligned}
\frac{1}{T}\ln\frac{y_j^T}{y_j^0} &= \beta_0 + \beta_1 \ln y_j^0 + \beta_2[\ln(IEXPY_j^0) * \ln(ExportIntensity_j^0)] \\
&+ \beta_3[\ln\left(\frac{EXPY_j^0}{IEXPY_j^0}\right) * \ln(ExportIntensity_j^0)] \\
&+ \beta_4 \ln(ExportIntensity_j^0) + \beta_5 X_j^0 + u_j
\end{aligned}
$$

Export intensity is defined as the ratio of the country's exports of goods and services with respect to GDP and the data are collected from the World Bank.[3] Table 5 shows both the OLS and the IV estimations (columns 1 to 3 and 4 to 6, respectively). We find that the interactions of $IEXPY$ and the $EXPY/IEXPY$ with export intensity are positive and significant at the 1-percent level, whereas the coefficient of the level of export intensity is negative and also significant at the 1-percent level.[4] Therefore, the positive and significant impact of international relocation (as measured by the $IIPR$ ratio) is increasing in the country's export openness. The marginal effect of product relocation, as measured by the ratio $EXPY/IEXPY$, also depends on export intensity. In particular, our estimates indicate that for the median value of export intensity, an increase in $EXPY/IEXPY$ of one standard deviation of $\ln(EXPY/IEXPY)$ (i.e., 0.083) would increase annual per capita GDP growth by 0.7 percentage points. Tak-

[3]Exports for United Arab Emirates before 2001 have been estimated using the percentage change in the volume of exports of goods and services from World Economic Outlook (IMF). We have then converted the estimated series in constant local currency units (LCU) to current US with official exchange rates and the implicit price deflator for GDP.

[4]We obtained almost identical results using other indicators of openness such as the share of exports plus imports on GDP, real openness or real export openness (using GDPpc in PPP terms in the denominator).

ing a country from the 1st quartile to the 3rd quartile along the distribution of $EXPY/IEXPY$ increases annual per capita GDP growth by 0.6 percentage points. Columns (4) to (6) show that results hold both when the $SPEXPYs$ are used as instruments of $EXPYs$.

Table 5: Export Openness and the Impact of Relocation

	Dependent variable: Growth rate of GDP per capita					
	OLS			*IV*		
	(1)	(2)	(3)	(4)	(5)	(6)
log initial GDP pc	-0.0142***	-0.0127***	-0.0139***	-0.0139***	-0.0120***	-0.0135***
	(0.00424)	(0.00455)	(0.00429)	(0.00435)	(0.00451)	(0.00437)
log IEXPY		0.0211**			0.0181**	
		(0.00823)			(0.00798)	
log EXPY/IEXPY	0.0902***			0.0672***		
	(0.0210)			(0.0210)		
logIEXPY*log ExportIntensity	0.00726***		0.00712***	0.00664***		0.00643***
	(0.00219)		(0.00221)	(0.00226)		(0.00227)
log(EXPY/EXPYI)*log ExportIntensity		0.0253***	0.0246***		0.0205***	0.0191***
		(0.00600)	(0.00582)		(0.00560)	(0.00558)
log human capital	0.00559**	0.00531**	0.00569**	0.00614***	0.00578**	0.00615***
	(0.00235)	(0.00243)	(0.00238)	(0.00232)	(0.00237)	(0.00232)
Rule of law	0.00141	0.00135	0.00135	0.00217	0.00189	0.00201
	(0.00214)	(0.00218)	(0.00213)	(0.00218)	(0.00222)	(0.00217)
log ExportIntensity	-0.0663***	-0.00290	-0.0682***	-0.0610***	-0.00266	-0.0616***
	(0.0203)	(0.00271)	(0.0204)	(0.0211)	(0.00260)	(0.0210)
Constant	0.125***	-0.0698	0.134***	0.125***	-0.0486	0.130***
	(0.0360)	(0.0454)	(0.0358)	(0.0375)	(0.0427)	(0.0367)
Observations	111	111	111	111	111	111
R^2	0.359	0.333	0.361	0.350	0.326	0.353

Notes: Dependent variable is the average growth rate of GDP per capita over the period 1995-2007. All variables are in natural logs except rule of law. The number of observations is the same as the number of exporting countries. The estimation method is OLS and 2SLS, respectively. The F-tests indicate that instruments are jointly significant in the first stage. Robust standard errors in parentheses. Significance levels: *** 10-percent, ** 5-percent, * 1-percent.

Our estimates also confirm previous results showing that the positive impact of initial export sophistication also increases with the county's export intensity and that export intensity has a positive impact on growth only as long as exports have a sufficiently high level of sophistication. According to the estimation in column 3, for the median value of export intensity (which is 3.44 in logs; that is, exports represents 31% of the country's GDP) an increase in $IEXPY$ of one standard deviation of $\ln IEXPY$ (i.e., 0.48) would raise annual per capita GDP growth by 1.2 percentage points. For the same value of export intensity, going from the 1st quartile to the 3rd quartile along the distribution of $\ln IEXPY$ increases annual GDP per capita growth by 1.9 percentage points. Compared to the results obtained in Table 3, the positive effect on growth of the initial export sophistication increases with export openness to trade.

Openness has a negative impact on growth for roughly half of the countries in the sample, which are those with low initial export sophistication. Assessing the effect of export intensity requires taking into account the interaction terms, since the impact of export openness also depends on $IEXPY$ and $EXPY/IEXPY$. Given that the first and the third quartiles of the distribution of export intensity in logs are 3.14 and 3.86 (i.e., exports representing 23.2% and 47.4% of country's GDP respectively), a country with an sophistication index relative to the 3rd quartile (an $IEXPY$ of 13,364\$; 9.5 in logs) and a value of $EXPY/IEXPY$ relative to the third quartile (that is 1.19; 0.73 in logs) that increases its openness from the 1st quartile to the 3rd quartile along the distribution of $\ln ExportIntensity$ would have a positive impact on annual pcGDP growth of 0.26 percentage points.

4 Concluding Comments

This paper analyzes the process of international relocation of production over the 1995-2007 period and its impact on economic growth across countries. First, we analyze the relocation process over this period using data to up to 5.000 products at the HS 6-digit level. We find that, from an aggregate perspective, the intensity of international relocation of production has remained surprisingly constant over the period. However, the analysis at the sector level reveals substantial heterogeneity and important relocation processes. The changes in the income level of the average exporter of each sector is only very weakly related to the sector's initial sophistication. Among the sectors with high initial $PRODY$ (high initial sophistication), we identify both industries whose production is relocating towards high income countries (e.g., pharmaceuticals), as well as industries whose production is relocating downwards in the exporters' income ladder (e.g., motor vehicles). Similarly, among the sectors with low initial $PRODY$, we find sectors that are moving upwards (e.g., iron and its manufactures) and industries moving downwards still further (e.g., textiles). Second, we assess the impact of these changes on cross-country growth. We find that countries that were specialized at the beginning of the period in product categories showing a relocation process towards low-wage (advanced) economies over the following 1995-2007 period, exhibit significantly lower (greater) growth over that period. Moreover, the quantitative impact of this effect increases with the economies' export intensity. However, the waves across products of both innovation and standardization are largely unpredictable and, therefore, it appears to be difficult for countries to gear their specialization towards the sectors and products that will experience more intense innovation in the future.

Appendix

Table 6: List of countries used in the regression analysis

ISO3	Country name
ALB	Albania
DZA	Algeria
ARM	Armenia
AUS	Australia
AUT	Austria
BHR	Bahrain
BGD	Bangladesh
BLX	Benelux
BEN	Benin
BOL	Bolivia
BRA	Brazil
BGR	Bulgaria
KHM	Cambodia
CMR	Cameroon
CAN	Canada
CHL	Chile
CHN	China
COL	Colombia
ZAR	Congo, Dem. Rep.
COG	Congo, Rep.
CRI	Costa Rica
CIV	Cote d'Ivoire
HRV	Croatia
CYP	Cyprus
CZE	Czech Republic
DNK	Denmark
DOM	Dominican Republic
ECU	Ecuador
EGY	Egypt, Arab Rep.
SLV	El Salvador
EST	Estonia
FJI	Fiji
FIN	Finland
FRA	France
GAB	Gabon
GMB	Gambia, The
DEU	Germany
GHA	Ghana
GRC	Greece
GTM	Guatemala

ISO3	Country name
GUY	Guyana
HND	Honduras
HKG	Hong Kong SAR, China
HUN	Hungary
IND	India
IDN	Indonesia
IRN	Iran, Islamic Rep.
IRL	Ireland
ISR	Israel
ITA	Italy
JPN	Japan
JOR	Jordan
KAZ	Kazakhstan
KEN	Kenya
KOR	Korea, Rep.
KWT	Kuwait
KGZ	Kyrgyz Republic
LAO	Lao PDR
LVA	Latvia
LTU	Lithuania
MWI	Malawi
MYS	Malaysia
MRT	Mauritania
MUS	Mauritius
MEX	Mexico
MDA	Moldova
MNG	Mongolia
MAR	Morocco
MOZ	Mozambique
NPL	Nepal
NLD	Netherlands
NZL	New Zealand
NIC	Nicaragua
NOR	Norway
PAK	Pakistan
PAN	Panama
PNG	Papua New Guinea
PRY	Paraguay
PER	Peru
PHL	Philippines

ISO3	Country name
POL	Poland
PRT	Portugal
ROM	Romania
RUS	Russian Federation
SAU	Saudi Arabia
SEN	Senegal
SGP	Singapore
SVK	Slovak Republic
SVN	Slovenia
ZAF	South Africa
ESP	Spain
LKA	Sri Lanka
SWE	Sweden
CHE	Switzerland
TJK	Tajikistan
TZA	Tanzania
THA	Thailand
TGO	Togo
TTO	Trinidad and Tobago
TUN	Tunisia
TUR	Turkey
UGA	Uganda
UKR	Ukraine
ARE	United Arab Emirates
GBR	United Kingdom
USA	United States
URY	Uruguay
VEN	Venezuela, RB
VNM	Vietnam
YEM	Yemen, Rep.
ZMB	Zambia

Table 7: Descriptive statistics

Statistic	Mean	Median	St. Dev.	Min	Max	Observations
GDP pc	10,776	6,649.6	11,717.4	375.2	68,201.4	111
IEXPY	10,107.9	10,405.9	4,303.3	2,503.7	18,117.6	111
EXPY	11,575.6	11,716.3	5,074.9	2,325.5	21,099.8	111
EXPY/IEXPY	1.14	1.15	0.09	0.88	1.37	111
Export Intensity	38.35	31.18	25.48	7.26	183.01	111

	Mean	Median	St. Dev.	Min	Max	Observations
GDPpc growth (%)	2.76	2.44	2.03	-2.07	9.61	111
log IEXPY	9.12	9.25	0.48	7.83	9.80	111
log EXPY	9.24	9.37	0.51	7.75	9.96	111
log(EXPY/IEXPY)	0.13	0.14	0.08	-0.12	0.32	111
log Export Intensity	3.48	3.44	0.56	1.98	5.21	111

Note: GDP per capita and the EXPYs are measured in US$; export intensity is exports of goods and services as a percentage of GDP. The EXPY indexes are defined in subsection 3.2.

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