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The Relevance of Productive Experience in the Process of Economic Growth: an Empirical Study[1]

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Abstract

The purpose of this study is to analyse the effects of productive experience in the process of economic growth. To do this, we estimate an augmented version of the Solow growth model where we include a measure called *centrality* among the set of usual explanatory variables. This variable summarizes the overall usefulness of a country's productive experience and it is computed as in Freitas and Salvado (2009), following Hausmann and Klinger (2007). In general, we failed to find a robust relationship between *centrality* and subsequent growth. This result casts doubts on the usefulness of the *centrality* measure in the prediction of economic growth.

[1] This paper is an improved version of my Masters' thesis presented at Universidade Nova de Lisboa. It was developed with the collaboration of Gabinete de Estratégia e Estudos, Ministério da Economia e da Inovação.
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1. Introduction

The existence of great disparities in the income level of countries has been motivating the literature on growth over the last decades. Among the vast set of studies in this field, there is a branch that views economic development and growth as a process of structural transformation where countries concentrate on the production of "rich-country goods" instead of "poor-country goods". This process will presumably raise the competitiveness of countries in the world markets.

The aim of this study is to provide a better understanding of how the economic performance of a country can be affected by the type and characteristics of the sectors and products in which a country specializes. We are interested in showing how countries that are specialized in the production of products whose productive capabilities can be easily adapted to the production of other goods are in a better position to begin their process of structural transformation and, therefore, have a greater potential for growth in the long-run.

To do this, we estimate an empirical augmented version of the Solow growth model, where among the usual set of explanatory variables, we include a measure of the relative position of a country in the product space. This measure is called *centrality* and it was proposed by Hausmann and Klinger (2007) and also estimated in Freitas and Salvado (2009). It intends to capture the extent to which the current specialization pattern of a country can be adapted to the production of other goods. Our main idea is to check whether countries that are specialized in industries that can be easily adapted to the production of other goods have higher growth in the long-run. Hence, to test the impact of this variable on growth, we estimate a dynamic panel growth model using data from 52 countries between 1985 and 2004.

Another question that arises is whether the fact that the capabilities used in the production of the current export basket of a country being more easily adapted to the production of upscale goods is better for growth than if they are more easily adapted to the production of less valued goods. To address this we valuate the goods according to the methodology introduced by Hausmann, Hwang and Rodrik (2005) and we use PRODY, a measure that gives the income level contained in a given product. Then, following Freitas and Salvado (2009), we compute *centrality* for three PRODY classes: high, medium and low and test whether their impact on growth is in fact different.

To assess whether the effects of *centrality* differ according to the income level of countries we also allow for some non-linearity in the growth equations by interacting *centrality* with the initial per capita GDP of each country.

The remaining of the paper is organized as follows: Section 2 presents the theoretical models that motivate our study. Section 3 refers to the methodology used, namely to the computation of the variable of interest, *centrality*, and to the growth model to be estimated. Section 4 refers to the data used and Section 5 presents the results. Finally, Section 6 concludes.

2. Theoretical Background and Motivation

The typical approach followed to study the economic performance of nations has been to try to identify the determinants that prevent the process of convergence among countries. The majority of the existing empirical work adopts the framework of the Solow model (1956) and explains growth rate differentials by relying on variables that represent a country's resources such as the investment rate, the population growth rate and the technology growth rate. This type of model was extended in the 1980s with the introduction of the so-called new growth theory, where technological change is assumed to be endogenously determined, for example, due to the accumulation of human capital as suggested by Lucas (1988). Hence, more recent empirical studies account for the effects of other economic and political variables, such as human capital, public expenditures, inequality, rate of openness, democracy, corruption, religion, among others.

There is an extensive literature focusing on the relation between trade and economic growth and it is mainly based on the "export-led" growth hypothesis. The majority of the empirical studies covering this subject have concentrated on measuring the impact on growth of the size of exports. Nevertheless, a few authors have been stressing the importance of the structure of the current specialization pattern of a country's exports in its process of economic development. In particular, some point out the damages resulting form natural based economies. For example, Prebisch (1959) argued that the terms of trade of primary commodities tend to decline over time, while others have addressed the possibility of an inverse relationship between natural resources and human and physical capital accumulation as well as productivity growth. Some of the few empirical studies in this subject are those of Sachs and Warner (2001), who found a negative impact of resource abundance on growth. The results of Lederman and Maloney (2003) indicate the opposite and argue that natural resources seem to have a greater potential for productivity growth. Other studies focus on the impact of export diversification on economic development. Lederman and Maloney (2003) have found evidence that export diversification is beneficial for growth. Hesse (2008), has estimated a dynamic panel growth model to test the impact of export concentration, as measured by the Herfindahl index, on per capita GDP growth. He found a negative relationship between these two variables.

There are some recent studies that also stress the importance of the nature of the specialization pattern of the current export baskets of countries for economic growth. In particular, Hausmann and Rodrik (2003) developed a model of self-discovery, where specialization patterns of a country are not uniquely determined by the usual fundamentals such as endowments and institutions but they may also be dependent on the number of entrepreneurs that engage in cost discovery (idiosyncratic element). They argue that the process of discovering the underlying cost structure of the economy is uncertain and that entrepreneurs face a great risk when they attempt to produce a good for the first time. In fact, if they succeed, the other entrepreneurs will emulate the incumbent and the externality becomes socialized. However, if they do not succeed, the losses remain private. This knowledge externality leads to sub-optimal levels of investment unless the government can find a way to internalize it.

The work of Hausmann, Hwang and Rodrik (2005) can be understood in this context. They defend that "some traded goods are associated with higher productivity levels than others and that countries that latch on to higher productivity goods (through the cost discovery process just described) will perform better." They then introduce a measure aimed to identify the degree of sophistication of goods, which they call PRODY. This index ranks traded goods in terms of their implied productivity (goods that are exported by richer countries get ranked highly than goods that are exported by poorer countries). They also propose a measure of the income level contained in a country's export basket, which they call EXPY (a weighted sum of the PRODY values of goods exported by each country). They find a positive relationship between a country's per capita GDP growth and this variable (even when controlling for endogeneity). Therefore, according to their reasoning, countries that latch on industries that are better positioned on this quality spectrum will benefit more from globalization and have a greater potential for growth and development in the long-run.

Hausmann and Klinger (2007) construct a model of the product space where the evolution of comparative advantage of a country depends on the patterns of relatedness or distance between products. They found that the product space is very heterogeneous and that it will be easier for a country to initialize its process of structural transformation if its export basket is located in an area where goods are highly inter-connected. In their model, each industry requires highly specific inputs such as human capital, physical capital, infrastructure, property rights or other. Thus, changing to a new industry will be difficult and may affect growth. They argue that the degree of substitutability of human capital in the production of different goods is not perfect and decreases with distance. In fact, if the goods require similar inputs and endowments they are closer together but if they require very distinct capabilities then they will be farther apart. Hence, the capabilities needed to produce a given product will be easily transferred to more nearby goods. Consequently, changes in comparative advantage will be dependent on the distance between goods. In fact, this process of incremental structural transformation will only happen if the costs of adapting product-specific human capital do not outweigh the private benefits of individual workers (the degree to which the price of the new good exceeds the price of the current good); otherwise, the economy will stagnate and will enter a situation which may be socially sub-optimal.

Furthermore, they represent the product-space using a matrix of *pairwise* distances between products, which are estimated as the conditional probability of a country having relative comparative advantage (RCA, Balassa, 1965) in one product given that it has comparative advantage in another product. They also construct a *centrality* index which is just the sum of the *pairwise* distances for that product. Goods that have a higher *centrality* will be those that are in a denser part of the product space and whose human capital can be easily adapted to the production of a larger number of products. Their results indicate that manufactured goods tend to be those in the centre of the product space, with a higher number of connections, while on the periphery we can find mainly primary and agricultural products. They also found evidence that rich (poor) countries tend to be specialized in dense (sparse) parts of the product space.

In a recent study concerning the opportunities for Portuguese structural transformation, Freitas and Salvado (2009) construct a measure of relatedness between products that introduces some novelties regarding the methodology developed by Hausmann and Klinger. This measure is estimated by means of a PROBIT model and it gives the increment in the probability of a country developing comparative advantage in one product given that it already has comparative advantage in another product. It is called the *Revealed Relatedness Index* (RRI). Then, using this RRI, they compute the *centrality* index for a sample of countries and find that it is positively correlated with per capita GDP, confirming the Hausmann and Klinger results. Hence, “a country should be better off when specialized in goods whose productive experience is helpful to produce a large set of other goods than when specialized in goods whose productive experience can hardly be adapted to produce other goods”.

This paper intends to contribute to this discussion by developing an empirical analysis where we test the relevance of a country’s productive experience, as measured by the *centrality* index, for its economic growth. This is achieved through the estimation of an augmented Solow growth equation, where we add the *centrality* index, as developed by Freitas and Salvado (2009), to the set of the standard explanatory variables. Since the productivity of the sectors in which a country specializes appears to be determinant for growth, we are also interested in addressing this question. Moreover, we will try to find if a country whose productive capabilities are more useful to produce high productivity goods (as measured by PRODY) has greater potential for growth than a country whose productive experience is more easily adapted to the production of low productivity goods.

3. Methodology

In the following two sections we explain the methodology behind our empirical analysis, that is, we provide a deeper description about our main variable of interest, the *centrality* index, and about the growth model to be estimated.

3.1. Centrality

In the model introduced by Hausmann and Klinger (2007), human capital is highly product-specific and cannot be perfectly substitutable. There are costs from moving to the production of new products and these costs rise with the distance between goods. To assess the usefulness of the productive experience with one good in the production of other goods, they have constructed a measure of product relatedness. They call this measure *proximity* and it is estimated as the conditional probability of a country developing comparative advantage in one product given that is has comparative advantage in another product. However, this measure is not symmetric and therefore, they focus on the minimum of the pairs of conditional probabilities.

In this study, however, the proximity between products is measured according to the methodology developed by Freitas and Salvado (2009). They have estimated a similar measure of relatedness between goods where the main difference lies in the fact that they run a PROBIT model instead of computing the minimum of the conditional probabilities. They call this measure *Revealed Relatedness Index* and define it, for each year, as the increment in probability of a country having RCA in one product given that it has RCA in another product. Their method improves the estimation of the relatedness index because it only accounts for the RRIs that are statistically significant, it allows for RRIs to be either positive or negative, and it does not require the matrix of RRIs to be symmetric.

To assess whether a given product is in a dense or in a sparse part of the product space, Freitas and Salvado (2009) propose a measure at the product-level, the *outpath*, which is computed as the column-total in the matrix of RRIs:

$$outpath_i = \sum_j RRI_{ij} \tag{1}$$

This measure gives the extent to which the capabilities used in the production of a particular good *i* can be adapted to produce other goods *j*.

At the country-level, to assess the extent to which the current specialization pattern of a country provides it with relevant productive experience to produce other goods, we use the methodology of Freitas and Salvado (2009) and compute an indicator called *centrality*. This is just the sum, for each year, of the *outpaths* of the products in which country *c* has comparative advantage:

$$centrality_c = \sum_{i:RCA_{ic}>1} outpath_i \tag{2}$$

Although we are interested in the helpfulness of the current specialization pattern of a country to produce other goods, we are also interested in the productivity value of these other goods. In fact, according to the theoretical models presented in section 2, we would expect that a country that is more central in the production of goods whose current productive capabilities can be easily adapted to the production of high value goods would be in a better position to start the process of structural transformation than if its current capabilities were easily adapted to the production of low value goods.

Therefore, following Freitas and Salvado (2009), we use the PRODY index to classify the value of the "arrival" products *j*. This measure was proposed by Hausmann et al. (2005) and it is defined as the income level associated with a given product. It is computed as a weighted average of the per capita GDPs of countries exporting that product. Using the notation in Freitas and Salvado (2009), we compute the PRODY index for each product *i* as follows:

$$PRODY_i = \sum_{c \in C} \sigma_{ci} Y_c \tag{3}$$

with $\sigma_{ic} = \dfrac{RCA_{ic}}{\sum_{d \in C} RCA_{id}}$ for $C = \{1,2,....,M\}$,

where Y_C is the real per capita GDP of each country *c* in 2000 constant prices, M is the number of countries (which equals 52 in this paper) and the weights σ_{ci} normalize the Balassa index of Revealed

Comparative Advantage, given by $RCA_{ic} = \frac{X_{ic}/X_c}{X_i/X}$,of country *c* with respect to all the countries exporting the same product.

Then, proceeding as in Freitas and Salvado (2009) we rank the goods according to their PRODY values. Moreover, they have divided their 1245 goods according to five PRODY classes. Since our number of goods is significantly lower (786), we divide the goods *j* according to three PRODY classes: high, medium and low. Then, we follow the methodology explained above to calculate *centrality* in each of the categories of PRODY. Illustrating, to obtain *centrality* in high PRODY goods we calculate the *outpath* for each product *i* by summing only the RRIs that relate it with each high PRODY product *j*. Then, we calculate *centrality* in high PRODY goods by summing the *outpaths* of every product *i* where the country *c* has comparative advantage.

3.2. Growth Model

We adopt the methodology of previous empirical work on economic growth which has repeatedly used the framework of the Solow growth model. In particular, we adapt the notation in Hoeffler (2002) in the remaining of this section.

In the augmented version of the Solow model, growth in output per worker is a function of initial output per worker, $y(0)$, the initial level of technology, $A(0)$, the rate of technological progress, g, the rate of investment in physical capital, s^k, the rate of investment in human capital, s^h , the depreciation rate, δ , the growth rate of the labour force, n , the share of physical capital in output, α , the share of human capital in output, γ, and the rate of convergence to the steady-state, ψ. Higher savings and human capital will increase the growth rate of output per worker, while higher labour force growth, when adjusted for depreciation and technological progress, is expected to have a negative impact on growth in output per worker. A country's growth rate in the steady-state in period *t* can be approximated by the following equation:

$$\begin{aligned}\ln y(t) - \ln y(0) = &-(1-e^{-\psi t})\ln y(0) + (1-e^{-\psi t})\ln A(0) + gt \\ &+ (1-e^{-\psi t})\frac{\alpha}{1-\alpha-\gamma}\left[\ln(s^k) - \ln(n+g+\delta)\right] \\ &+ (1-e^{-\psi t})\frac{\gamma}{1-\alpha-\gamma}\left[\ln(s^h) - \ln(n+g+\delta)\right]\end{aligned} \tag{4}$$

There is an extensive literature focusing on the limitations of cross sectional growth regressions. In fact, cross sectional regressions do not account for the fact that most variables are endogenously determined. For example, the initial level of income is correlated with the dependent growth variable (Knight, Loayza and Villanueva (1993); and most macroeconomic variables are interdependent as shown by Caselli et al. (1996). Furthermore, cross section methods do not allow us to analyze any dynamic relationships between the variables over time while dynamic panel regressions allow us to explore the time series dimension of the data for each country. Finally, there may be also a substantial omitted variable bias induced by the correlation of unobserved time invariant country-specific factors, such as the initial level of technology, with the variables of interest.

In order to overcome these problems, we use a panel data model that allows us to account for the time-invariant country specific effects. Hence, we estimate a dynamic growth equation of the following form:

$$y_{i,t} - y_{i,t-1} = \alpha + \beta y_{i,t-1} + \gamma X'_{i,t} + \mu_t + \eta_i + \upsilon_{i,t} \quad (5)$$

where the term in the left is the logarithmic difference of per worker GDP of country *i* over a series of five year periods, $y_{i,t-1}$ is the logarithm of per worker GDP at the beginning of each of these periods, $X'_{i,t}$ is a vector of characteristics or potential determinants of growth measured either at the beginning of each period, or as an average over each of the periods. As referred above, these commonly include the savings rate, population growth rate, rate of technological progress, rate of depreciation and human capital. To capture any productivity changes that are common to all countries we include period-specific intercepts (μ_t). We also include unobserved time-invariant country-specific effects to account for differences in the initial level of technology (η_i).

Equation (5) can be, alternatively, expressed as:

$$y_{i,t} = \alpha + \beta^* y_{i,t-1} + \gamma X'_{i,t} + \mu_t + \eta_i + \upsilon_{i,t} \quad (6)$$

where $\beta^* = (\beta + 1)$.

Omitting permanent unobserved country specifics effects in a dynamic panel data model will make Ordinary Least Squares (*OLS*) levels estimates to be biased and inconsistent since the lagged dependent variable $y_{i,t-1}$ is positively correlated with the country-specific effects, η_i.

One way to avoid this omitted variable problem is to use the within groups estimator (*WG*). This method eliminates the time-invariant country-specific effects by subtracting the time series means of each variable for each country when estimating equation (6). The resulting model is then estimated by *OLS.* However, this fixed effects estimator is biased and not consistent when applied to dynamic panel growth regressions due to the presence of the lagged dependent variable of per capita GDP which is also a function of the country-specific effects η_i. The assumption of no correlation between η_i and the explanatory variables required by the within-groups estimator is then violated.

In order to address this problem, we follow the strategy of Hansen (1982), Arellano and Bond (1991) and Caselli et al. (1996) and use a first-difference Generalized Method of Moments (*DIF-GMM*) estimator, where we take first differences of equation (6) thereby eliminating the country-specific effects η_i:

$$(y_{i,t} - y_{i,t-1}) = \beta^* (y_{i,t-1} - y_{i,t-2}) + \gamma (X'_{i,t} - X'_{i,t-1}) + \mu_t + (\upsilon_{i,t} - \upsilon_{i,t-1}) \quad (7)$$

However, *OLS* estimates of (7) will not be consistent since this differencing induces a moving-average structure of the transformed error term that is correlated with the differenced lagged dependent variable. We have to find valid instruments for $\Delta y_{i,t-1} = (y_{i,t-1} - y_{i,t-2})$. As long as the errors are independent across countries and do not exhibit autocorrelation, $E(\upsilon_{it}\upsilon_{is}) = 0$ for $s \neq t$, and that $E(y_{i1}\upsilon_{it}) = 0$ for $t \geq 2$, it is possible to use as instruments values of $y_{i,t}$ lagged two periods or more, since $y_{i,t-2}$ and earlier values are correlated with $\Delta y_{i,t-1}$ but not with $\Delta\upsilon_{it}$.

If the regressor $X'_{i,t}$ is strictly exogenous, i.e., if $E(X'_{i,t}\,\upsilon_{is}) = 0$ for all s,t, we are able to use all the past, present and future values of $X'_{i,t}$ as instruments, even if the $X'_{i,t}$ are correlated with η_i. However, the variables contained in $X'_{i,t}$ are generally thought to be endogenous in growth theory. This means that current and past shocks to GDP are correlated with current values of $X'_{i,t}$, i.e. $E(X'_{i,t}\,\upsilon_{is}) \neq 0$ for $s < t$ and $E(X'_{i,t}\,\upsilon_{is}) = 0$ for $s > t$ only. Therefore, we can use as instruments for the differenced equation values of the endogenous variables in $X'_{i,t}$ lagged two periods or more.

Nevertheless, according to Blundell and Bond (1998) and Arellano and Bover (1995), levels may be weak instruments for current differences when the explanatory variables are very persistent (close to a random walk) and the time series are very short. Hence, the instruments will be only weakly correlated with the endogenous variables and the *GMM* estimates will suffer from large finite sample bias.

They propose a system *GMM* estimator (*SYS-GMM*) that combines a system of equations that includes the differenced equation (7) for which we use lagged levels of $y_{i,t}$ and of $X'_{i,t}$ as instruments as discussed for the first-differenced *GMM*; and the levels equation (6). As long as $E(\Delta X'_{i,t}\,\eta_i) = 0$, i.e., changes in $X'_{i,t}$ are uncorrelated with η_i (weaker condition than requiring the levels of $X'_{i,t}$ to be uncorrelated with η_i), and that $E(\Delta y_{i2}\,\eta_i) = 0$, we can use $\Delta y_{i,t-1}$ and $\Delta X'_{i,t}$ as instruments in the levels equation.

We can assess the validity of the set of instruments by performing Sargan tests of overidentifying restrictions.

4. Data

In this paper, we use a balanced panel that includes information on 52 countries from 1985 to 2004. The data was averaged across five-year periods from 1985-1989, 1990-1994, 1995-1999 and 2000-2004.

According to the framework suggested by the augmented Solow model, the dependent variable is per capita GDP growth over five-year periods and adjusted for purchasing power parity. The explanatory variables are the initial level of per capita income of the period and the average investment share of GDP over each five-year period, which we use as a proxy for average savings rate. We also take the natural logarithm of the sum of the population growth variable and the technological progress and depreciation rate, which are commonly assumed in the literature to be constant across countries and to amount to 0.05.

Human capital is accounted for by including a measure of average years of schooling for population aged 15 and over, which has been taken from Barro and Lee (2000). We have included in the regressions the degree of openness as a further control variable.

Our main variable of interest is the logarithm of *centrality*, which has been calculated according to the methodology of Freitas and Salvado (2009). We have used their dataset on the RRIs and RCAs (2009), which they have constructed using data from the Revision 2 of the SITC at a 4-digit desegregation level for 786 products of the UN COMTRADE dataset.

5. Results

In this section, we begin with a short analysis of *centrality*. The variability of *centrality* is easily observed from Figure 1 in Appendix A, where we plot the value for *centrality* in 1986 against *centrality* in 2004. Countries that are closer to the 45 degrees line are those whose *centrality* had not changed much since the beginning until the end of the considered period. We can see that there are countries, such as Algeria, Ecuador, Venezuela and Jamaica, that were scarcely central in 1986 and that in 2004 had not changed much their position. On the other hand, countries such as Germany, Italy and France are obviously detached of the previous group, presenting very high values for centrality both in 1986 and in 2004. Nevertheless, it is worth noticing that some of these better positioned countries have experienced a decrease in *centrality* during the course of the period, as one can easily see for Germany, for example. Other countries, such as China and Poland have clearly improved their *centrality* over these 19 years. This supports the fact that the *centrality* variable presents a lot of variability, both across time and across different countries.

We should also notice that all the three *centrality* variables are positively correlated with a country's per capita GDP over the entire period. In fact, from Table 2 we can see that total centrality presents a correlation coefficient with per capita GDP equal to 58.65%. *Centrality* in high PRODY goods and in low PRODY goods are also positively correlated with a country's per capita GDP, with correlation coefficients equal to 10.3% and 68.92%, respectively. However, this is a simple correlation and we are not controlling for any other factors.

To examine this relationship more carefully we have to consider the results for the augmented Solow model including the *centrality* variables among the usual set of explanatory variables (Appendix B). All regressions include time dummies and all reported standard errors are robust to heteroskedasticity. As pointed out in Hoeffler (2002), for finite samples, such as ours, the two-step estimators can lead to standard errors that are seriously biased downwards. Therefore, we report the one-step estimates for the GMM estimations.

We have first estimated the textbook Solow model and the augmented Solow model (Tables 4 and 5, respectively). As suggested by the Solow model, the dependent variable is per capita GDP growth and we can interpret the negative coefficient on initial GDP as conditional convergence. The coefficient on investment is expected to have a positive sign, while the opposite is valid for the coefficient on the population growth variable. For the textbook Solow model (Table 4) our results indicate that initial GDP and investment are significant at the 1% level when using OLS (column (1)). The population growth variable is also significant but only at the 10% level. The estimates of the within groups estimator and system GMM (columns (2) and (4), respectively) indicate that initial GDP and investment are significant at the 1% level. For the first-difference GMM (column (3)) we find that only initial GDP appears to significantly affect per capita GDP growth. The population growth variable was never significant when using the last three estimation procedures.

In what concerns to the augmented Solow model (Table 5), the results indicate that only initial GDP and investment are significant regardless of the method used in the estimation. Our estimates also report a coefficient on human capital that is never significant, and a coefficient on the population growth variable that is only significant when using OLS. The result we obtain for human capital is accordant with other empirical studies. For example, Hoeffler (2002) has estimated an unbalanced panel with 6 time periods and 85 countries and his estimates report a coefficient on human capital that is also never significant when considering any of the four estimators. However, in our work, the population growth variable is not significant when we use estimators other than OLS. Since the population growth variable was always significant in Hoeffler's results, it is possible that we have some finite sample bias in our results.

We now present the estimates for the augmented Solow model with the set of explanatory variables including the natural logarithm of *centrality*. The estimates for this specification of the model are presented in Table 6. First, we have run an OLS regression (column (1)) where we found all explanatory variables, with the exception of population growth rate and average years of schooling (human capital), to be significant and to have the expected sign. *Centrality* appears to have a significant (at the 1% level) and positive impact on growth equal to approximately 4%. We have also used the within groups, the first-difference and system GMM estimators to estimate this equation (columns (3), (5) and (7), respectively). However, *centrality* no longer appears to be significant according to the results of any of these estimators. In fact, only the coefficients on the initial GDP and investment variables appear to be significant regardless of the estimation procedure used. In this specification of the model, the population growth and human capital variables are never significant.

Column (2) in Table 6 presents the OLS estimates for the same model but including an additional variable which introduces some non-linearity in the effect of *centrality* on growth. All the variables, except population growth and human capital, are significant. Now the effect of *centrality* on growth is non-linear and we have to be careful when interpreting the results. If we consider the OLS estimates, we can see that there is evidence for a decreasing effect of *centrality* as the level of development of countries rises. In fact, it seems that richer countries benefit much less or do not benefit at all of having higher *centrality*. For example, if we consider the OLS results (column (2)), we can see that for a developed country such as the United States (natural logarithm of GDP per capita equal to 10.35 in the period 1995-1999), the effect of *centrality* on next period's per capita GDP growth will be given by $0.46 - (0.05 \times 10.35) = -0.03 = -3\%$. Nevertheless, for a less developed country such as India (whose natural logarithm of GDP per capita is equal to 7.74 in the period 1995-1999), the effect of *centrality* on economic growth will still be positive, being given by $0.46 - (0.05 \times 7.74) = 0.073 = 7.3\%$.

The within groups estimator (column (4)) reports different results, with the coefficients for the variable *centrality* alone and interacted with the initial level of the country, not being significant even at the 10% level. With this estimator, only investment is significant. Furthermore, all the variables with the exception of investment are not significant when we use the first-difference GMM (column (6)). The estimates from the system GMM (column (8)) confirm the OLS results since the effect of *centrality* on growth appears to be decreasing with the level of development of countries, although the variables are significant only at the 10% level. We should notice that the Sargan test does not reject the validity of the instruments at the 5% level.

We now distinguish *centrality* according to the PRODY classes of the ”arrival” products *j*. Table 7 presents the estimates for the growth equation (5) but including among the standard Solow explanatory variables, two more variables: *centrality* in high PRODY goods and *centrality* in low PRODY goods. We exclude *centrality* in medium PRODY goods because it was not significant in any of the specifications of the model.

When we do not consider the possibility of non-linearity in the effect of both *centrality* classes, we find that only the coefficient for *centrality* in low PRODY goods is significant (although only at the 10% level) when using the OLS estimator (column (1)). The estimated impact on growth of having higher *centrality* in low PRODY goods is approximately 2.6%. Initial income, investment and openness also present coefficients that are significant and have the expected sign. When using the within groups estimator (column (3)), the *centrality* in low PRODY goods variable is no longer significant for growth. When considering the first-difference and system GMM results (columns (5) and (7), respectively), only the coefficients on initial income and investment are significant.

We also allow for some non-linearity in this specification of the model by interacting *centrality* in the two PRODY classes with the initial level of income of countries. When considering the OLS results (column (2)), we can see that none of the *centrality* variables is significant. For the within groups and first-difference GMM estimators (column (4) and (6)), only investment is significant, while the system GMM results (column (8)) indicate that only investment and initial income are significant at the 1% level. The coefficients on the variables respecting to *centrality* in high PRODY goods are significant at the 10% level. Notice, however, that the Sargan test rejects the validity of the instrumental variable set at the 5% significance level.

In summary, our results indicate that, in general, there is no evidence for a robust relationship between the *centrality* variable and per capita GDP growth. In fact, while the OLS estimates indicate a strongly significant impact of this variable on growth, the other estimation methods indicate the opposite.

When considering the possibility of non-linearity in the relationship between total *centrality* and growth, there is a somewhat weak indication for the effect of *centrality* on growth to be decreasing with the level of development of countries. This result is maintained when we consider the relationship between *centrality* in high PRODY goods and the dependent variable.

Overall, the *centrality* variables do not seem to explain much of per capita GDP growth. This suggests that *centrality* may not be the best measure to capture the relevance of a country's productive experience for growth.

In fact, a possible shortcoming of this variable is that it is a measure of the overall productive experience that does not take into account if the country already has comparative advantage in the "arrival" products. Perhaps it would be preferable to use a measure that would incorporate this distinction. One possibility would be the inclusion of a country-level measure similar to the *Open Forest* proposed by Hausmann and Klinger (2006). It is a measure of the sophistication level of those products that an economy could potentially produce given its current productive capabilities, i.e. a measure of the value of the unoccupied product space.

6. Conclusion

In this study, we investigated the relationship between the overall centrality of countries and their per capita GDP growth. This relationship is positive and significant when using OLS although when adopting other estimation procedures the results do not indicate the same.

We have also tried to find if countries whose productive experience is more easily adapted to high income products have a greater economic performance than those whose productive experience is more easily adapted to low income goods. We found that the effect of *centrality* according to the PRODY classes of the "arrival" products also does not appear to be a good predictor of a nation's economic performance.

Therefore, in general, we cannot say that there is evidence for the *centrality* variable to explain much of a country's economic growth.

The results in this paper could be improved in future research. In particular, we could extend the dataset on the RRIS and RCAs and obtain an unbalanced panel with far more observations. This would possibly reduce any finite sample bias in our results. In fact, our panel consisted only of 4 periods and 52 countries, and when using the first-difference and the system GMM, we ended up with few useful observations.

We could also eliminate the endogeneity introduced in the regressions by the centrality variables in high and low PRODY classes. In fact, PRODY is computed as a weighted average of per capita GDPs of the countries that export a given commodity. Hence, when we divide the goods according to their PRODY classes, we may be introducing endogeneity in our model, since the *centrality* variables according to the PRODY classes are related to per capita GDP by construction. We could eliminate this problem by including in the regressions the *centrality* variables lagged one period. Nonetheless, this would reduce even more our number of observations; therefore, this solution should only be adopted if we extended the panel. Another possibility would be the computation of country-specific PRODYs by excluding own exports, as done by Hausmann, Hwang and Rodrik (2005). Then, the calculation of *centrality* by PRODY classes for each country would be done according to the classes suggested by those country-specific PRODYs.

Finally, we should also reconsider the way the centrality variable is computed and, perhaps, investigate other variables that could be used to summarize the usefulness of a country's productive experience.

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Appendices

A. Data

Real GDP per capita – adjusted for purchasing power parity and based on a chain index. It was obtained from Penn World Table (PWT) 6.2.

Investment share of GDP – average over the five-year periods (1985-1989, 1990-1994, 1995-1999 and 2000-2004). The data was obtained from PWT 6.2.

Population – average population growth rate was computed as the difference between the natural logarithms of total population at the end and beginning of each five-year period and dividing this difference by the number of years. The data on total population was obtained from the World Bank Development Indicators (WDI).

Technological progress and depreciation rates – assumed to be constant across countries and to sum 0.05.

Human Capital – we use average years of schooling for the population aged 15 or over as a proxy for this variable. The data was obtained from Barro and Lee (2000) and it is provided quinquennially, at the beginning of each period (1985, 1990, 1995 and 2000).

Openness – it is the total trade as a percentage of GDP and it is computed as Exports plus Imports divided by Real GDP per capita. The data was obtained from PWT 6.2.

Centrality – this measure is averaged over the five-year periods and it is computed as explained in Section 3.2. The data on the RRIs and RCAs is from the dataset of Freitas and Salvado (2009) and it is available from 1986 to 2004. For the period 1985-2004, we computed the average centrality as the average of four years.

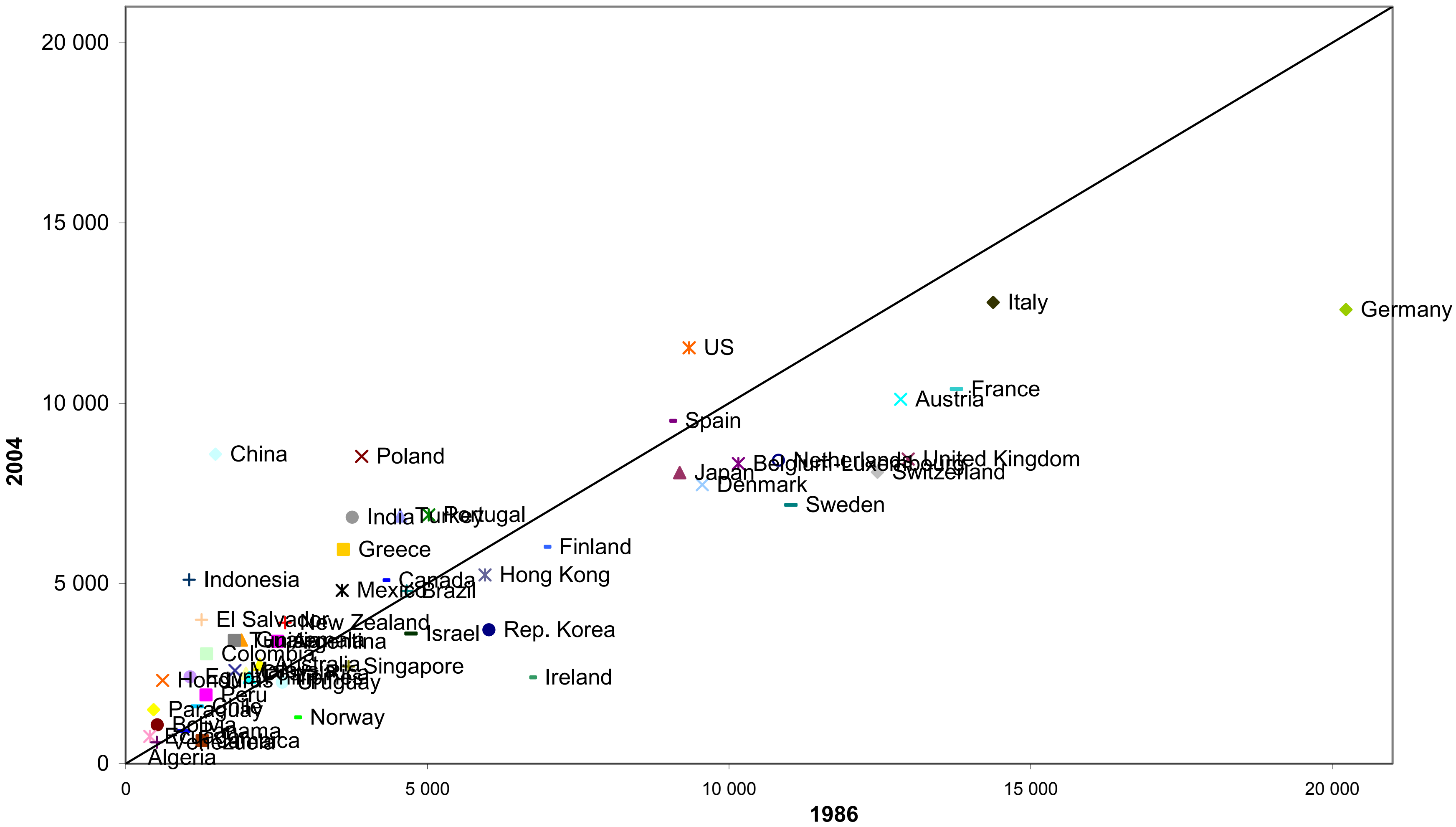

Figure 1: Evolution of Centrality between 1986 and 2004

Variable	Mean	Std. Dev.	Min	Max	Observations
GDP p.c.					
Overall	9.204	0.807	7.220	10.460	N = 208
Between		0.799	7.670	10.295	n = 52
Within		0.148	8.592	9.812	T = 4
Investment					
Overall	-1.744	0.416	-3.040	-0.860	N = 208
Between		0.400	-2.798	-0.983	n = 52
Within		0.125	-2.304	-1.324	T = 4
log (n + g + δ)					
Overall	-2.816	0.110	-3.030	-2.530	N = 208
Between		0.103	-2.970	-2.633	n = 52
Within		0.039	-2.956	-2.679	T = 4
Human Capital					
Overall	1.934	0.345	1.040	2.490	N = 208
Between		0.337	1.145	2.470	n = 52
Within		0.085	1.682	2.134	T = 4
Openness					
overall	-0.566	0.669	-2.280	1.400	N = 208
between		0.635	-1.818	1.185	n = 52
within		0.222	-1.429	0.041	T = 4
Centrality					
overall	8.158	0.941	5.000	9.850	N = 208
between		0.926	5.238	9.703	n = 52
within		0.202	7.535	8.670	T = 4
Centr. High PRODY					
overall	6.754	0.698	3.940	8.020	N = 208
between		0.661	4.220	7.828	n = 52
within		0.240	6.001	7.351	T = 4
Centr. Low PRODY					
overall	7.118	1.248	3.320	9.280	N = 208
between		1.238	3.983	9.185	n = 52
within		0.218	6.365	7.775	T = 4

Table 1: Descriptive Statistics

Variable	GDP p.c.	Investment	log (n + g + δ)	Human Capital	Openness	Centrality	Centr. High PRODY	Centr. Low PRODY
GDP p.c.	1							
Investment	0.6639	1						
log (n + g + δ)	-0.6052	-0.4621	1					
Human Capital	0.7786	0.6238	-0.5317	1				
Openness	0.1963	0.2539	0.0617	0.1332	1			
Centrality	0.5865	0.4995	-0.6589	0.4586	-0.0761	1		
Centr. High PRODY	0.103	0.2001	-0.3641	0.0658	-0.1079	0.7676	1	
Centr. Low PRODY	0.6892	0.5439	-0.6675	0.5268	-0.0659	0.9683	0.6048	1

Table 2: Parwise Correlations

	Country		Country
1	Algeria	*27*	Israel
2	Argentina	*28*	Italy
3	Australia	*29*	Jamaica
4	Austria	*30*	Japan
5	Belgium-Luxembourg*	*31*	Malaysia
6	Bolivia	*32*	Mexico
7	Brazil	*33*	Netherlands
8	Canada	*34*	New Zealand
9	Chile	*35*	Norway
10	China	*36*	Panama
11	Colombia	*37*	Paraguay
12	Costa Rica	*38*	Peru
13	Denmark	*39*	Philippines
14	Ecuador	*40*	Poland
15	Egypt	*41*	Portugal
16	El Salvador	*42*	Rep. Korea
17	Finland	*43*	Singapore
18	France	*44*	Spain
19	Germany	*45*	Sweden
20	Greece	*46*	Switzerland
21	Guatemala	*47*	Tunisia
22	Honduras	*48*	Turkey
23	Hong Kong	*49*	United Kingdom
24	India	*50*	United States
25	Indonesia	*51*	Uruguay
26	Ireland	*52*	Venezuela

*The export data for these two countries was only available separately since 1999, therefore, they are considered together.

Table 3: List of Countries

B. Results

Dependent Variable Δ log GDP				
	(1)	(2)	(3)	(4)
Estimation	*OLS*	*WG*	*DIF-GMM*	*SYS-GMM*
Observations	208	208	104	156
Intercept	0.5520	3.1500		-0.3370
	(0.2872)*	(0.9239)***		(1.3937)
log GDP_{t-1}	-0.0626	-0.2331	-0.1079	-0.0969
	(0.0225)***	(0.0735)***	(0.1074)***	(0.0535)***
log Investment	0.1617	0.1684	0.5339	0.3920
	(0.0409)***	(0.0585)***	(0.4418)	(0.0885)***
log (n + g + δ)	-0.1401	0.2264	-0.3780	-0.7110
	(0.0816)*	(0.2226)	(1.2282)	(0.6197)
Sargan Test			0.9758	0.0303

*Robust standard errors in parenthesis: *significant at 10%; **significant at 5%; ***significant at 1%*
All equations include time dummy variables for each period
The figures reported for the Sargan tests are the p-values of the null-hypothesis.

Table 4: Estimation results for the textbook Solow model

Dependent Variable Δ log GDP				
	(1)	(2)	(3)	(4)
Estimation	*OLS*	*WG*	*DIF-GMM*	*SYS-GMM*
Observations	208	208	104	156
Intercept	0.5594	3.0547		-0.6355
	(0.2939)*	(0.9331)***		(1.4305)
log GDP_{t-1}	-0.0652	-0.2342	-0.1166	-0.0722
	(0.0250)***	(0.0729)***	(0.0767)***	(0.0455)***
log Investment	0.1595	0.1709	0.5705	0.3588
	(0.0404)***	(0.0595)***	(0.1969)***	(0.0666)***
log (n + g + δ)	-0.1372	0.2365	-0.3712	-0.8745
	(0.0825)*	(0.2227)	(0.7481)	(0.6086)
log Human Capital	0.011	0.0714	0.1957	-0.2272
	(0.0298)	(0.1169)	(0.2598)	(0.1739)
Sargan Test			0.9945	0.0247

*Robust standard errors in parenthesis: *significant at 10%; **significant at 5%; ***significant at 1%*
All equations include time dummy variables for each period
The figures reported for the Sargan tests are the p-values of the null-hypothesis.

Table 5: Estimation results for the augmented Solow model

Dependent Variable Δ log GDP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimation	*OLS*	*OLS*	*WG*	*WG*	*DIF-GMM*	*DIF-GMM*	*SYS-GMM*	*SYS-GMM*
Observations	208	208	208	208	104	104	156	156
Intercept	0.6295	-2.9957	3.0074	-0.3888			0.1468	-5.7288
	(0.2795)**	(1.0422)***	(1.0393)***	(2.5588)			(1.0045)	(3.7374)
log GDP_{t-1}	-0.0793	0.3168	-0.2317	0.1672	-0.1368	-0.4673	-0.1075	0.6683
	(0.0231)***	(0.1076)***	(0.0779)***	(0.3131)	(0.0758)***	(1.1797)	(0.0359)***	(0.4639)***
log Investment	0.1273	0.1122	0.1583	0.1643	0.5378	0.5501	0.2365	0.2388
	(0.0377)***	(0.0345)***	(0.0623)**	(0.0683)**	(0.1752)***	(0.1700)***	(0.0670)***	(0.0598)***
log $(n + g + \delta)$	-0.0183	-0.0505	0.2548	0.2419	-0.6372	-0.6288	-0.3865	-0.1752
	(0.080)	(0.0766)	(0.2034)	(0.1793)	(0.6722)	(0.6866)	(0.4034)	(0.3195)
log Human Capital	0.0271	0.01395	0.0678	0.0366	0.2207	0.2427	-0.1373	-0.1738
	(0.0327)	(0.0326)	(0.1214)	(0.1259)	(0.3186)	(0.3034)	(0.1175)	(0.1257)
log Openness	0.0274	0.0325	0.0297	0.0439	0.0589	0.0316	0.0555	0.0114
	(0.0115)**	(0.0117)***	(0.0479)	(0.0500)	(0.0773)	(0.1295)	(0.0392)	(0.0345)
log Centrality	0.0393	0.4588	0.0095	0.4360	0.0204	-0.3382	0.0675	0.7753
	(0.0137)***	(0.1179)***	(0.0289)	(0.3508)	(0.0689)	(1.2783)	(0.0440)	(0.4201)*
log Centrality*log GDP_{t-1}		-0.0468		-0.0492		0.0408		-0.0846
		(0.0127)***		(0.0402)		(0.1446)		(0.0489)*
Sargan Test					0.6907	0.6262	0.0015	0.0794

*Robust standard errors in parenthesis: *significant at 10%; **significant at 5%; ***significant at 1%*

All equations include time dummy variables for each period

The figures reported for the Sargan tests are the p-values of the null-hypothesis.

Table 6: Estimation results for *centrality*

Dependent Variable Δ log GDP								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimation	*OLS*	*OLS*	*WG*	*WG*	*DIF-GMM*	*DIF-GMM*	*SYS-GMM*	*SYS-GMM*
Observations	208	208	208	208	104	104	156	156
Intercept	0.6830	-2.5585	2.9938	0.9763			0.7646	-6.3241
	(0.3404)**	(0.9925)**	(1.0435)***	(2.3589)			(0.8791)	(3.4227)*
log GDP_{t-1}	-0.0821	0.2749	-0.2278	0.0094	-0.2356	-0.0535	-0.1356	0.7848
	(0.0255)***	(0.1001)***	(0.0851)***	(0.2933)	(0.1385)***	(1.2250)	(0.0644)***	(0.4151)***
log Investment	0.1253	0.1115	0.1557	0.1607	0.7046	0.7058	0.2422	0.2333
	(0.0371)***	(0.0351)***	(0.0641)**	(0.0714)**	(0.2206)***	(0.2066)***	(0.0771)***	(0.0668)***
log $(n + g + \delta)$	-0.0184	-0.0510	0.2592	0.2536	-0.8228	-0.5957	-0.3234	0.0424
	(0.0781)	(0.0746)	(0.2066)	(0.1911)	(0.5527)	(0.5865)	(0.3592)	(0.2657)
log Human Capital	0.0304	0.0133	0.0632	0.0431	0.5774	0.5181	-0.0789	-0.1330
	(0.0330)	(0.0313)	(0.1248)	(0.1350)	(0.3675)	(0.3407)	(0.1156)	(0.1176)
log Openness	0.0284	0.0338	0.0304	0.0406	0.0268	0.0052	0.0683	0.0044
	(0.0118)**	(0.0117)***	(0.0484)	(0.0523)	(0.0972)	(0.1478)	(0.0471)	(0.0376)
log Centrality High PRODY	0.0145	0.2606	0.0104	0.1640	-0.1020	0.9446	0.0062	0.9548
	(0.0174)	(0.1835)	(0.0260)	(0.4145)	(0.1760)	(1.3674)	(0.0403)	(0.5776)*
log Centrality Low PRODY	0.0261	0.2175	0.0003	0.1389	-0.0265	-0.7989	0.0322	0.1209
	(0.0143)*	(0.1416)	(0.0265)	(0.3261)	(0.0892)	(1.3264)	(0.0369)	(0.4407)
log Centrality High PRODY*log GDP_{t-1}		-0.0277		-0.0168		-0.1149		-0.1019
		(0.0190)		(0.0457)		(0.1528)		(0.0617)*
log Centrality Low PRODY*log GDP_{t-1}		-0.0215		-0.0167		0.0913		-0.0150
		(0.0149)		(0.0394)		(0.1517)		(0.0479)
					0.7534	0.6219	0.0000	0.0313

*Robust standard errors in parenthesis: *significant at 10%; **significant at 5%; ***significant at 1%*
All equations include time dummy variables for each period
The figures reported for the Sargan tests are the p-values of the null-hypothesis.

Table 7: Estimation results for *centrality* in high and low PRODY goods