JOURNAL OF ECONOMIC DEVELOPMENT
Volume 41, Number 4, December 2016

THE DYNAMICS OF TOTAL FACTOR PRODUCTIVITY AND INSTITUTIONS

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This article examines the dynamics of Total factor Productivity (TFP). It uses Phillips and Sul's (2007) method to test for cross-country TFP convergence and the Arellano and Bover (1995) and Blundell and Bond (1998) system GMM estimator to examine the factors driving TFP growth. Data from 1960 to 2011 for 63 countries are utilized in the analysis. The convergence test provides strong evidence against global TFP convergence, but indicates the existence of TFP clubs. The empirical work also shows that initial conditions play a fundamental role on the dynamics of TFP: economies that started with lower TFP remained below initially better-positioned economies. This study finds evidence that institutional quality and openness are very important determinants of TFP growth. While better institutions promote technological progress and efficiency, globalization works as an important channel for knowledge and technological diffusion among nations, which fosters TFP growth.

Keywords: TFP, Convergence, Institutions, Openness
JEL Classification: O3, O47

1. INTRODUCTION

The work of Solow (1957) and Abramovitz (1956) and more recent analyses (Casseli, 2005; Hall and Jones, 1999) demonstrate that total factor productivity (TFP) is the key driver of long-run income growth. Klenow and Rodriguez-Clare (1997) estimate that roughly 90 percent of the differences in growth of income per capita can be explained by differences in total factor productivity. It is also well documented that advanced economies (OECD) lead technological change and innovation while developing economies lag behind in the technological frontier and tend to adopt (with a lag) technologies developed in technology-leading countries (Besley and Case, 1993; Archibugiand and Pietrobelli, 2003). In addition, technologies created in leading

* I thank an anonymous referee for insightful comments and suggestions. All remaining errors are my own.

countries may not be appropriate to be used in technology-backward economies (Basu and Weil, 1998; Acemoglu and Zilibotti, 2001). Thus, there are significant differences in levels and growth of productivity between advanced and developing economies.

Studies examining cross-country TFP differences find strong evidence against global TFP convergence (Klenow and Rodriguez-Clare, 1997; Hall and Jones, 1999; Di Liberto et al. 2011). Di Liberto, Pigliaru and Chelucci (2011) show that most countries underperform "with respect to the U.S. in terms of TFP growth" (p.168) as well as that the TFP gap across countries is persistent.[1] While there is strong empirical evidence against global TFP convergence, there is evidence in favor of club convergence. Miller and Upadhyay (2002) group countries by income quartiles and find that there is absolute TFP convergence for countries in the lowest and highest income quartiles, but no convergence for countries in intermediate income quartiles. Kumar and Chen (2012) find that health and education have a significant positive effect on TFP and conditional TFP convergence. Papalia and Silvia's (2013) results also support club convergence. Madsen (2007, 2008) show that knowledge transmitted internationally through trade and patents has contributed significantly for TFP convergence among OECD countries. Di Liberto and Usai (2013) show that a polarization is taking place across European regions, with only a few regions emerging as TFP leaders while most regions are lagging behind, causing the TFP gap between these two clusters to widen.

Loko and Diouf (2009) provide a comprehensive discussion of the factors that determine TFP and might explain the patterns (convergence, or lack thereof) discussed above. For the sake of simplicity, this study groups the factors affecting TFP into three categories. The first group consists of macroeconomic factors that either hinder or boost productivity growth. Economic instability (e.g inflation), a large government, and taxation distortions supposedly create market inefficiencies and, thus, negatively affect productivity (Barro, 1991; Loko and Diouf, 2009). On the other hand, overall openness to international trade and capital mobility are expected to boost productivity growth. International trade spurs competition – which leads to innovation – as well as serves as a channel for technology diffusion among nations. Thus, economies that are more open to trade are expected to have higher productivity growth (Dollar and Kraay, 2004; Wacziarg and Welch, 2008; Barro and Sala-i-Martin, 1995). The same rationale applies to capital flows. Openness to capital flows (Foreign Direct Investment) is associated with technology diffusion and knowledge transfers, which in turn boosts productivity growth (Borensztein *et al*. 1998). The composition of output (i.e, if intensive in services, agriculture, or manufacturing) has also been identified as a driver of productivity growth. In particular, nonagricultural economies have experienced faster productivity growth (Poirson, 2000; Jaumotte and Spatafora, 2007).

The second group of factors includes variables that measure the quality of labor (human capital).[2] The rationale is that labor skills positively affect productivity because

[1] See Khan (2012) for a compressive review of the TFP/income convergence hypothesis literature.

[2] Several measures of human capital (or skills) have been suggested including years of education,

of its inherent contributions to capital productivity, innovation, and technological change. In addition, better labor skills may also increase the capability of an economy to benefit from externalities created by international trade and capital flows (Loko and Diouf, 2009).

The third group moves away from proximate factors (macroeconomic and labor quality) and focuses on deep-rooted factors (institutions) as the key factor determining productivity and income growth. The rationale is that institutions shape the incentives for both factor accumulation and innovation and, thus, play an important role in fostering technological change as well as improving the overall allocative efficiency of factors of production (North, 1990; Hall and Jones, 1999; Acemoglu et al., 2005; Dias and Tebaldi, 2012). Tebaldi and Elmslie (2013) find that institutional arrangements explain much of the cross-country variations in patent production, a proxy for technological innovation. Institutions also influence the efficiency of factors of production. More precisely, “bad” institutions may cause i) economic agents to engage in unproductive activities (rent seeking, theft, excess safety measures), ii) misallocation of factors among firms, iii) misallocation of factors among economic sectors and iv) create difficulties for the use of available efficiency-enhancing technologies (Tebaldi and Elmslie, 2008; Hsieh and Klenow, 2007). Therefore, institutions affect TFP via both technological progress and efficiency.

This study revisits the analysis of both convergence and the determinants of TFP growth and contributes to the literature in three particular ways. First, inherent difficulties in measuring TFP as well as identifying its determinants have left important questions either answered or subject to weak empirical evidence (Easterly and Levine, 2001; Casseli, 2005; Danquah *et al*., 2012). This study uses a newly released cross-country TFP dataset [PWT8.0] produced by Feenstra, Inklaar and Timmer (2015) to examine the dynamics of Total factor Productivity. The PWT8.0 data improve the measurement of cross-country TFP previously available by i) allowing the depreciation rate to change over time and across different capital goods and ii) using country-specific and year specific labor shares.

Second, this study sets itself apart from previous works that examine TFP convergence by utilizing a semi-parametric method proposed by Phillips and Sul (2007) to test for cross-country TFP convergence. This methodology is more adequate to examine convergence among time series than traditional cointegration tests (Phillips and Sul, 2007) and allows identifying clustering formation without having to impose a-priori ad-hoc assumptions about club membership.

Third, this paper circumvents the endogeneity and heterogeneity problem that plague cross-country regressions using OLS or traditional panel data. More precisely, we use five-year averages to build a cross-country panel dataset with eight periods including

proportion of the population with secondary and tertiary education, and more complicated calculations including a piecewise function of the weighted rate of returns for primary, secondary, and tertiary education (Hall and Jones, 1999, Psacharopoulos, 1994).

data for 1975-79, 1980-84, 1985-89, 1990-95, 1995-99, 2000-04, 2005-09, and 2010-2011. Then, the Arellano and Bover (1995) and Blundell and Bond (1998) system GMM estimator is utilized to examine the factors driving TFP growth. The regression analysis focuses mostly on variables that are related quality of institutions (group three above).

The rest of the paper is organized as follows: Section 2 discusses the methodology used to test for TFP convergence and presents the results of the convergence test. Section 3 uses the GMM method to examine the drivers of TFP growth, and Section 4 summarizes the paper's findings.

2. TFP CONVERGENCE

2.1. Methodology and Data

A large branch of the literature uses cointegration analysis to determine whether two or more series converge or diverge over time. However, sample size limitation is blamed for causing low power to detect cointegration. Moreover, cointegration does not necessarily imply convergence and the "conventional cointegration tests do not serve as adequate tests for convergence." (Phillips and Sul, 2007). An alternative test for convergence can be carried out by considering a methodology proposed by Phillips and Sul (2007). The methodology is motivated by a simple decomposition of a panel data. Let R_{it} denote human capital accumulation, where $i = 1, 2, \ldots, N,\ t = 1, 2, \ldots, T,\ N$ denotes the number of countries, and T is the sample size. The variable R_{it} can be decomposed into two components:

$$R_{it} = g_{it} + a_{it}, \tag{1}$$

where g_{it} is a systematic component, including permanent common components, and a_{it} represents transitory components. Phillips and Sul (2007) conveniently separate common from idiosyncratic components in the panel by rewriting equation 1 as follows:

$$R_{it} = \frac{(g_{it}+a_{it})}{R_t} R_t = \delta_{it} R_t, \quad \text{for all } i \text{ and } t, \tag{2}$$

where R_t represents the panel common component and δ_{it} is the time varying idiosyncratic term. Notice that δ_{it} can be interpreted as the relative TFP in terms of the panel average at time t and, therefore, it measures the economic distance between the common trend component R_t and R_{it}. Moreover, convergence requires that the common trend components (g_{it} and R_t) dominate the transitory term a_{it}.

Equation 2 implies that the transition parameter, δ_{it}, plays a crucial role in determining if a country's TFP moves together with TFP in another economy. More precisely, the trajectory of δ_{it} will determine if there is a common component in the trajectory of TFP between countries i and j, so that the TFP converges in the long-term. Instead, if the individual heterogeneity dominates then countries i and j will follow their own TFP paths and divergence takes place.

The test structure assumes that relative convergence of TFP between countries i and j takes place if:

$$\lim_{k \to \infty} \frac{R_{it+k}}{R_{jt+k}} = 1, \quad \text{for all } i, j. \tag{3}$$

If Equation 3 holds, then it implies that the transition parameter δ_{it} in equation 2 will converge to a constant, that is: $lim_{k\to\infty} R_{it+k}/R_{jt+k} = 1$, for all i and j. $\delta_{it+k} = \delta$.[3] In this paper's context, TFP convergence can be tested by estimating the transition parameter δ_{it} and determining whether it converges to a constant (or not). Phillips and Sul (2007)'s method to test for convergence using panel data consists of testing if the cross sectional variance of the relative transition parameters (δ_{it}) converges to zero (and δ_{it} converge to δ) as t tends to infinity. In order to execute the test, Phillips and Sul (2007) propose the log *t*-test, which consists of testing the cross sectional variance of the relative transition parameters, h_{it}, denoted by:

$$h_{it} = \frac{R_{it}}{N^{-1}\sum_{i=1}^{N} R_{it}} = \frac{\delta_{it}}{N^{-1}\sum_{i=1}^{N} \delta_{it}}. \tag{4}$$

The relative transition parameter, h_{it}, measures the transition coefficient δ_{it} for the i-th country in relation to the cross sectional average. It is also necessary to measure the cross sectional variance of the relative transition parameter:

$$H_t = N^{-1}\sum_{i=1}^{N}(h_{it} - 1)^2. \tag{5}$$

The log *t*-test is conducted by using a semi parametric specification for the time path of δ_{it}:

$$\delta_{it} = \delta_i + \frac{\sigma_i}{L(t)t^{\alpha}}\zeta_{it}, \; t \geq 1, \; \sigma_i > 0 \quad \text{for all } i, \tag{6}$$

where $L(t)$ is a slowly varying function, σ is the speed of convergence, and ζ is iid(0, 1).[4] This specification implies that δ_{it} converges to δ_i for all non-negative values of α. The test is carried out by specifying the null $(\mathcal{H}_0)$ and alternative $(\mathcal{H}_A)$ hypotheses of convergence as follows:

[3] For details about this condition, please refer to Phillips and Sul (2007).

[4] See Phillips and Sul (2007) for additional details about the model specification and assumptions related to the parameter ζ.

$\mathcal{H}_0$: $\delta_i = \delta$ for all i and $\alpha \geq 0$,

$\mathcal{H}_A$: $\delta_i \neq \delta$ for all i and $\alpha < 0$.

Under the null hypothesis, h_{it}, – which measures the transition coefficient δ_{it} for the i-th country in relation to the cross sectional average – converges to 1 and the cross sectional variance of the relative transition parameters, H_t, converges to zero. Phillips and Sul (2007) demonstrate that the log t-test can be carried out by deducing a simple regression equation where the cross sectional variance ratio H_1/H_t is regressed against $\log(t)$ as follows:

$$log\left(\frac{H_1}{H_t}\right) - 2 * logL(t) = a + b * log(t) + u_t, \quad (7)$$

where u is a random disturbance, $\log L(t) = \log(t+1)$, and $t = rT,\ rT+1,\ rT+2, \dots T$, with $r > 0$. For the sake of power and size, Phillips and Sul (2007) recommend setting $r = 0.3$. Equation 7 is estimated using OLS with an autocorrelation and heteroskedasticity robust covariance matrix. The test decision-rule consists of employing the standard one-sided t-test using $\hat{b}$. For instance, at the 5% level of significance the null hypothesis of convergence is rejected if $t_{\hat{b}} < -1.65$.

It is important to recognize that the rejection of the null hypothesis suggests that at least one economy deviates from the panel average. However, sub-groups within the panel may converge. To address this case, Phillips and Sul (2007) develop an algorithm that allows identifying clustering (clubs) within the panel using repeated log t regressions. The authors assume that there exists a core subgroup within the panel that converges. This core subgroup and subsequent subgroups can be identified through these four steps:

1) *Last observation ordering*: order the panel members according to the last observation in the panel.

2) *Core group formation*: select the highest members (based on step 1) of the core subgroup G_k, where $N > k \geq 2$. This step is completed by running the log t regression and executing the log t-test for this subgroup. The optimal subgroup size k^* is determined according to the rule: $k^* = \arg max_k\{t_k\}$ subject to $min\{t_k\} > -1.65$.

3) *Club membership:* panel members are selected to be included in the core group by adding one at a time, then by applying the procedure described in step 2. Then execute the log t-test to determine if the i-th individual member should be kept in the core group. This procedure needs to be repeated for the remaining individuals in the panel.

4) *Stopping rule:* the countries not selected to be part of the core group (step 3) form a complement group. Then run the log t-test for this subgroup to determine whether they

converge. If not, steps 1 to 3 should be repeated on this subgroup to determine other clubs (clustering).

This section of the paper uses TFP data from the Penn World Table 8.0 produced by Feenstra, Inklaar and Timmer (2015). The variable of interest is country i's TFP relative to the United States (USA TFP=1). The only criterion for sample selection is data availability starting in 1960. In addition, the long-run component from TFP is extracted by using the Hodrick-Prescott (HP) smoothing filter. This strategy eliminates the cyclical component (short-run) from the TFP series. As suggested in Maravall and del Rio (2001) and considering that this study uses annual data, the HP control parameter (λ) is set equal to seven.

2.2. Empirical Results

This study employs the method proposed by Phillips and Sul (2007) to test for convergence in relative TFP for a group of 63 countries for which the TFP data are available between 1960 and 2011. Table A1 in the appendix provides a list of countries included in the analysis.

A sequential approach is used to consider global and club convergence. First, a global test that includes all countries in the panel is performed. Next, countries are grouped by region and the log *t*-test is performed to identify patterns of convergence/divergence for the region. Then the clustering-algorithm proposed by Philips and Sul (2007) is used to search for clustering.

Table 1 reports the log t-test for the full panel. Not surprising, the test shows that the null hypothesis of convergence should be rejected at any standard levels of significance. This result provides evidence against global convergence in TFP and is consistent with previous studies (e.g. Klenow and Rodriguez-Clare 1997; Hall and Jones, 1999; Di Liberto *et al.*, 2011).

Table 1. TFP Convergence Test, 1960-2011

Coefficient on Log t	*t*-stat
-2.392***	-27.64

Notes: *** The null hypothesis of convergence is rejected at the 1% level of significance.

Table 2 reports the results considering regions (Advanced Economies; Asia & Pacific; Latin America & Caribbean; Middle East & North Africa; and Sub-Saharan Africa) as defined by the World Bank. The coefficients on the log t-test are negative and statistically significant for all regions, which imply that the convergence hypothesis should be rejected. This result also refutes convergence of TFP within regions and suggests that geographic clusters or economic clusters (Advanced economies) seem to play little role in explaining the dynamics of TFP. Together the results from Tables 1 and 2 provide strong evidence against the hypothesis of TFP convergence either globally or by regions.

These results, however, do not exclude the possibility of clustering and that TFP convergence may take place among group of countries. To address this issue, this study uses the algorithm proposed by Phillips and Sul (2007) to identify clustering within the panel. The use of the algorithm together with the log t-test suggests that six clubs exist.

Table 2. TFP Convergence Test by Region

Club	Country Members	Log-*t*-test	
		Coefficient	*t*-stat
Advanced Economies	Portugal, Japan, Greece, Iceland, Spain, New Zealand, Italy, Australia, Finland, Denmark, France, Belgium, Austria, Canada, Netherlands, Sweden, Switzerland, United Kingdom, Turkey, Luxembourg, Ireland, Norway	-2.149***	-14.73
Asia & Pacific	Philippines, Indonesia, China, Thailand, Malaysia, Korea, Republic of, Taiwan, Hong Kong, Singapore, Cyprus, Sri Lanka, India	-2.031***	-42.95
Latin America & Caribbean	Bolivia, Jamaica, Brazil, Ecuador, Peru, Colombia, Uruguay, Argentina, Costa Rica, Dominican Republic, Venezuela, Chile, Guatemala, Mexico.	-2.049***	-15.39
Middle East & North Africa	Jordan, Morocco, Tunisia, Egypt, Iran, Malta, Israel.	-3.035***	-9.19
Sub-Saharan Africa	Niger, Kenya, Tanzania, Senegal, Mozambique, Cameroon, Cote d`Ivoire, South Africa.	-1.784***	-52.15

Notes: *** The null hypothesis of convergence is rejected at the 1% level of significance.

However, the log *t*-test providences evidence that Niger and Kenya – low-income countries with the lowest TFP levels relative to the U.S. – are not members of any club and follow distinct TFP paths. For the sake of simplicity and consistency with the method used to identify these clubs, the clubs are ranked by relative TFP-growth with Club 1 being the slowest TFP-growing club and Club 6 the fastest TFP-growing club. Table 3 reports the identified clusters within the full panel.

Club 1's members are slow TFP-growing economies from sub-Saharan African (Tanzania, Senegal, Mozambique, Cameroon, Cote d`Ivoire) and Asia (Sri Lanka and Philippines). With 14 countries, Club 2's members are mostly from middle-income countries from Asia (India, China, Thailand, Malaysia), Latin America & Caribbean (Jamaica, Bolivia, Brazil, Colombia, Ecuador, Peru), and from the Middle East & North Africa (Jordan, Morocco, Tunisia). Club 3 has six countries from Latin America & Caribbean (Uruguay, Costa Rica, Argentina, Dominican Republic, Chile, and Guatemala) and two countries from Africa (Egypt and South Africa). With 19 countries, Club 4 includes countries from Asia, the Pacific area, Europe and Middle East. This club is comprised of three upper-middle income countries (Iran, Venezuela, and Mexico) and 16 high-income countries (Korea, Japan, New Zealand, Australia, Portugal, Greece, Cyprus, Iceland, Spain, Italy, Finland, Denmark, France, Belgium, Malta, Iran, and Israel. Clubs 5 and 6 include the fastest TFP-growing countries, which are all high-income countries with the exception of Turkey (upper -middle income). Club 5 includes Austria, Canada, Taiwan, The Netherlands, Sweden, Hong Kong, Switzerland and Singapore and Club 6 includes the UK, Turkey, Luxembourg, Ireland, and Norway.

Table 3. TFP Club Convergence Test, 1960-2011

Club*	Country Members	Log-*t*-test	
Club 1 [7]	Tanzania, Senegal, Mozambique, Cameroon, Sri Lanka, Cote d`Ivoire, Philippines	-0.2377	-0.80
Club 2 [14]	Bolivia, Jamaica, China, Jordan, Indonesia, Morocco, Thailand, India, Brazil, Tunisia, Ecuador, Peru, Colombia, Malaysia	-0.1722	-0.99
Club 3 [8]	Uruguay, Argentina, South Africa, Costa Rica, Dominican Republic, Egypt, Chile, Guatemala	-0.2716	-1.40
Club 4 [19]	Korea, Portugal, Venezuela, Japan, Mexico, Malta, Iran, Greece, Cyprus, Iceland, Spain, New Zealand, Israel, Italy, Australia, Finland, Denmark, France, Belgium	-0.1688	-1.00
Club 5 [8]	Austria, Canada, Taiwan, Netherlands, Sweden, Hong Kong, Switzerland, Singapore	0.2867	0.92
Club 6 [5]	United Kingdom, Turkey, Luxembourg, Ireland, Norway	-0.1191	-0.43
No-club [2]	Niger, Kenya,		-

Notes: * The number of club members is reported in brackets.

Figures 1 through 6 allow further assessing the dynamics of TFP among countries by plotting the relative transition parameters for all six clubs as well as for each country. Figure 1 plots the average relative transition parameters for all six clubs relative to the panel average. Three important patterns are observed in this figure. First, it shows that the relative position of five clubs has not changed over the last five decades. More precisely, initial relative-conditions are preserved over time: countries within relative low (high) TFP clubs continue to belong to low (high) TFP clubs. Second, Club 3 transitioned from the second-highest TFP club in the 1960s to the fourth-highest position in 2011. Third, the dispersion of TFP across clubs increased significantly over the last 5 decades. The relative TFP of countries in Club 6 was 2.5 times larger than that of countries in Club 1 in 1960 compared to 3.9 times in 2011. These findings altogether suggest a high degree of persistence in relative TFP and that the TFP gap is widening over time.

Figures 2 through 7 report the transition parameters for all countries within each of the six clubs. These figures show that the within-club variations in relative TFP have decreased significantly over time. Some countries, however, failed to maintain their relative advantageous position while other managed to catch up quickly. Figure 3, for instance, shows that Jordan, Morocco, and Jamaica experienced a relative decrease in their TFP over time. On the other hand, India and china experienced significant increases in their TFPs while Brazil's relative TFP stayed roughly constant over the period considered in this study. More precisely, China and India's transition parameters increased from about 0.46 in the early 1960s to 0.71 and 0.88, respectively, in 2011. The interpretation of these figures implies that, on average, India's TFP was about half that of the panel average by the 1960s, but its TFP has significantly increased and, as of 2011, represented 88 percent of the panel's average.

Overall, the results provide strong evidence against global or regional TFP convergence. The findings also suggest that geography seems to have limited effect on TFP clustering. While some European countries belong to the same TFP club, club membership seems to be driven by factors other than geography (e.g. European counties belong to more than one club). The results also imply that initial conditions play a very important role on the dynamics of TFP because most countries that started with low (high) relative TFP have remained below (above) an initially better-positioned (worse-positioned) economy. This finding is consistent with Lucas (1988) and Tebaldi and Elmslie (2013).

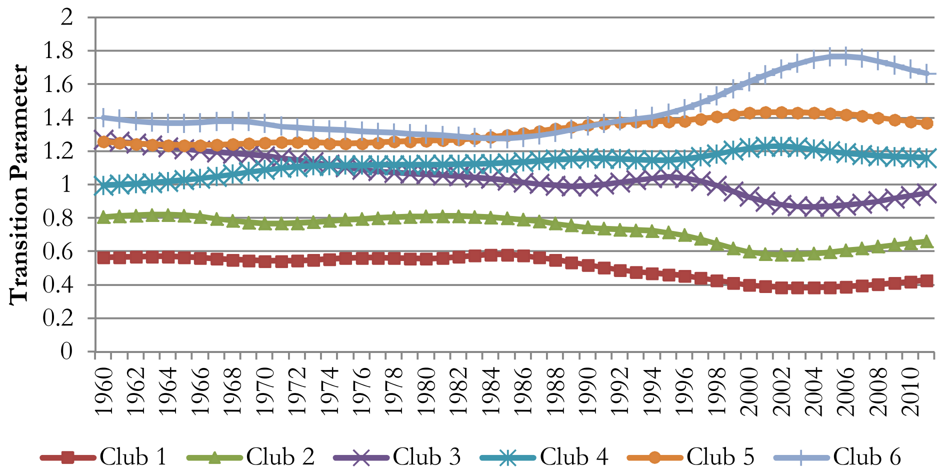

Figure 1. TFP Transition Curves, Club Average, 1960-2011

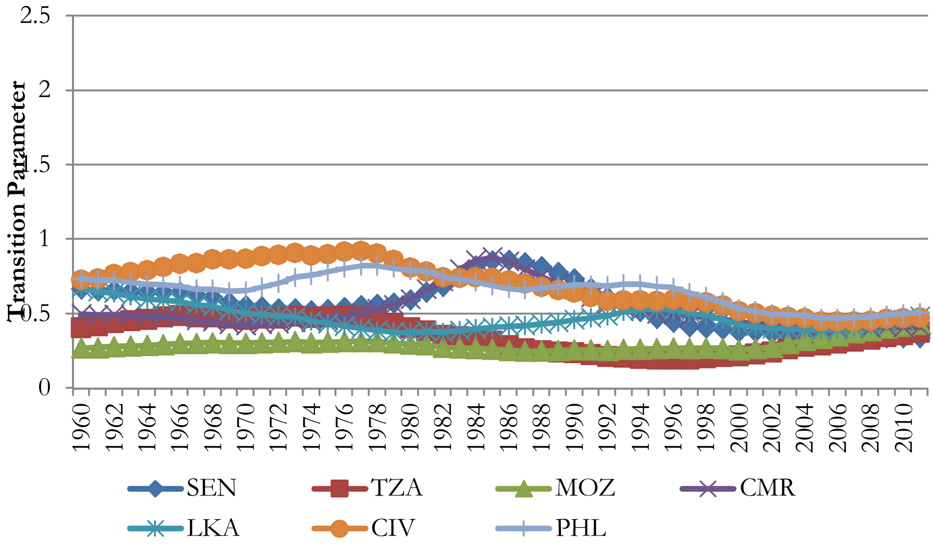

Figure 2. TFP Transition Curves, Club 1, 1960-2011

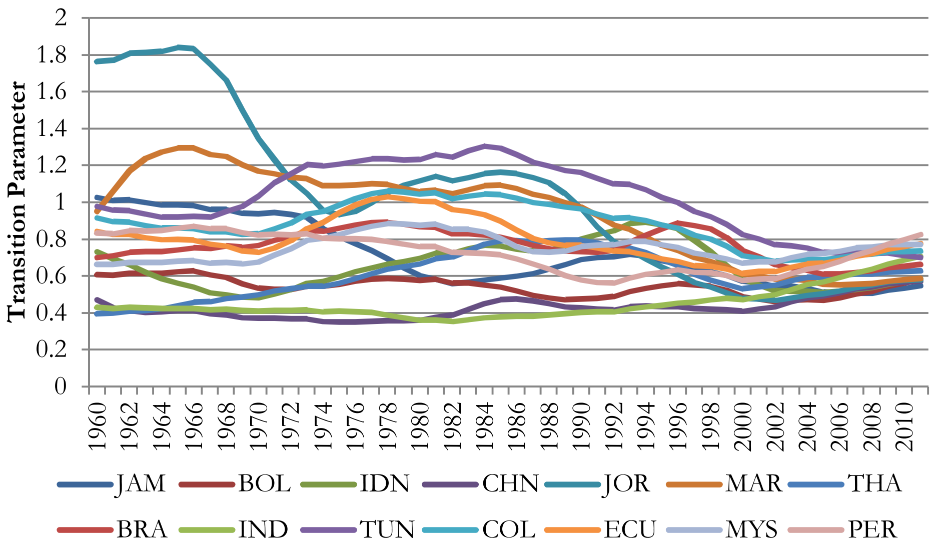

Figure 3. TFP Transition Curves, Club 2, 1960-2011

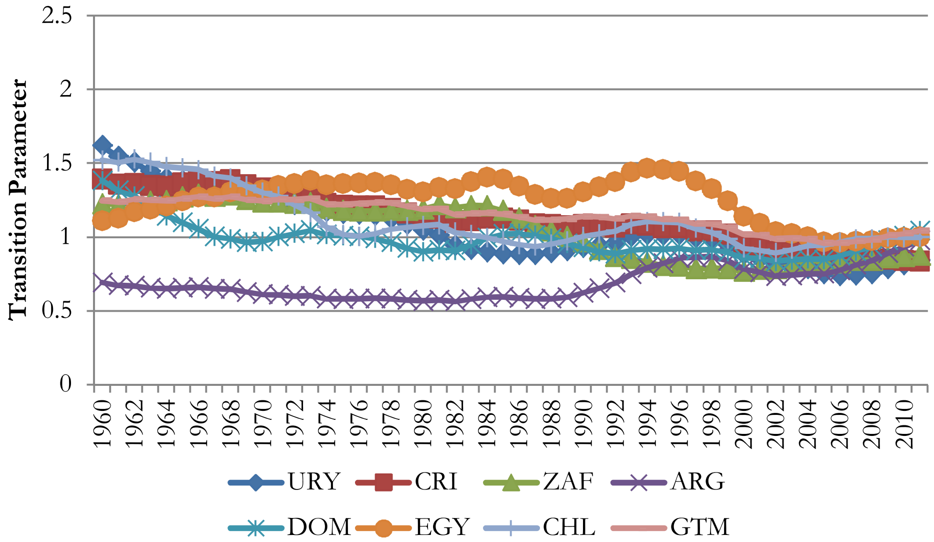

Figure 4. TFP Transition Curves, Club 3, 1960-2011

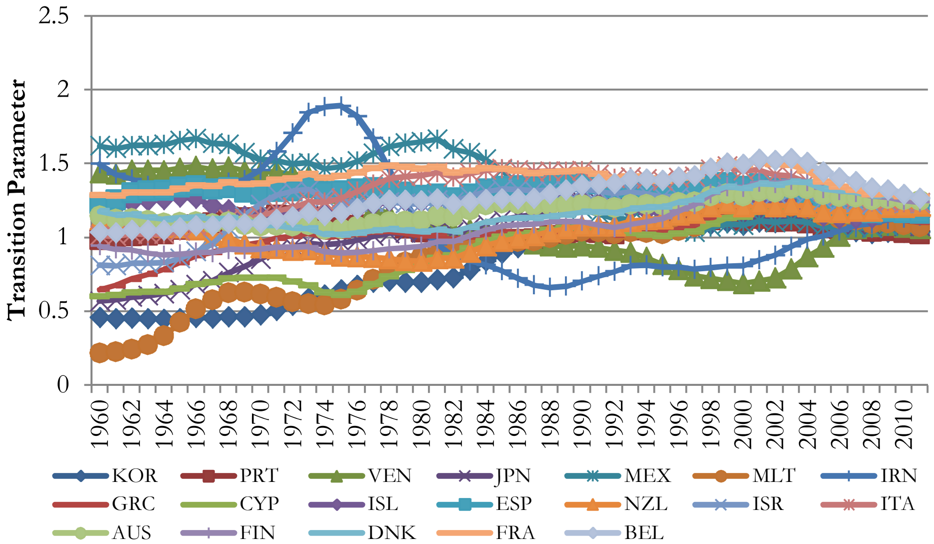

Figure 5. TFP Transition Curves, Club 4, 1960-2011

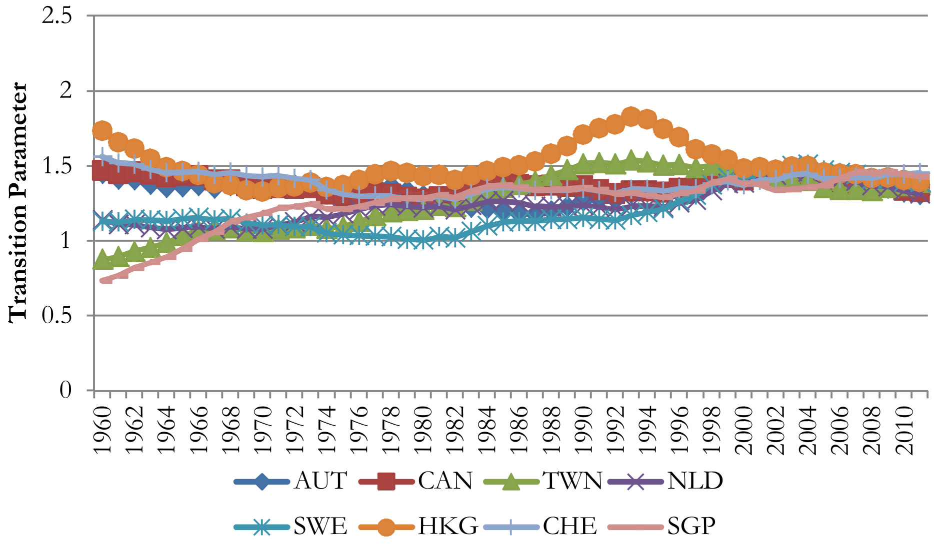

Figure 6. TFP Transition Curves, Club 5, 1960-2011

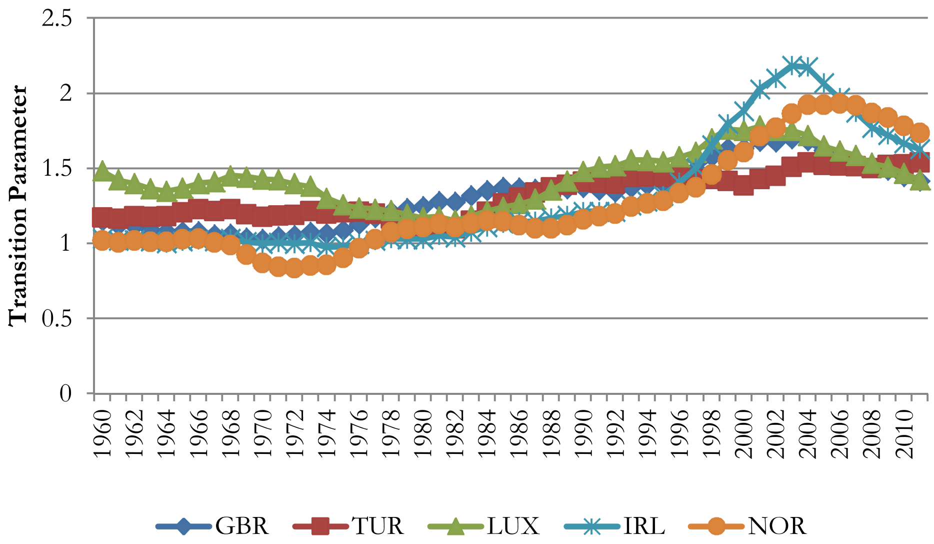

Figure 7. TFP Transition Curves, Club 6, 1960-2011

3. REGRESSION ANALYSIS

This section of the paper examines the factors driving TFP growth. Endogeneity and heterogeneity plague cross-country regressions and, thus, OLS or traditional panel data analyses are unsuitable for this task. To mitigate both endogeneity and heterogeneity, we use a dynamic panel data model. Consider the following dynamic specification:

$$TFP_{i,t} = \gamma TFP_{i,t-1} + w_{i.t}\alpha + \eta_i + u_{i,t}, \quad (8)$$

where i denotes country, t denotes time, TFP is the growth of relative total factor productivity, w is a vector of pre-determined and strictly exogenous variables, γ and α (vector) are coefficients, η represents the unobserved heterogeneity, and u is the error term. Arellano and Bond (1991) developed a method to estimate the model above using the generalized method of moments (GMM). The method consists of differentiating equation 8 in order to eliminate the heterogeneity, that is:

$$\Delta TFP_{i,t} = \gamma \Delta TFP_{i,t-1} + \Delta w_{i.t}\alpha + \Delta u_{i,t}. \quad (9)$$

Equations 8 and 9 form a system that can be estimated using moment conditions with lagged levels of all variables used as instruments for equation 8. Arellano and Bover (1995) and Blundell and Bond (1998) show that this GMM estimator performs quite poorly when the autoregressive process is too persistent. They propose an estimator that uses moment conditions with both lagged differences used as instruments for the level equation and moment conditions of lagged levels used as instruments for the differenced equation. This estimator, however, requires that the second-order autoregressive (AR(2)) process on the panel residuals should be zero (otherwise, the errors are serially correlated, which invalidates the model).[5] We estimate the model using the system GMM estimator proposed by Blundell and Bond (1998).

Several measures of institutions are included in the model and were taken from the dataset compiled by Teorell *et al.* (2013) and released by the QOG Institute including: i) The Political Constraints Index III measures the feasibility of policy change; ii) Independent Judiciary is a dummy variable coded one if there is an independent judiciary. This variable is generated based on information from Polity's Executive Constraints and – where available – on ICRG's index of Law & Order; iii) Quality of Government is measured using data from the International Country Risk Guide (ICRG). This variable is the mean value of Corruption, Law and Order and Bureaucracy Quality, which is scaled from 0 to 1. Higher values indicate better quality of government; iv) The Index of Democratization combines the percentage of votes not cast for the largest party (competition) times the percentage of the population who actually voted in the election (participation). The outcome is normalized to range from 0 (no democracy) to 100 (full

[5] See Roodman (2009) for details about testing for the autocorrelation.

democracy).

Openness is measured using three alternative variables. The globalization index is a weighted average of economic globalization (openness to trade), social globalization and political globalization. This measure of openness was suggested by Dreher (2006) and Dreher, Gaston and Martens (2008). Merchandise exports as a % of GDP and merchandise imports as a % of GDP are also considered in the model. These two variables are taken from the Penn World Table 8.0. Economic specialization is measured using two variables: Industry share of the economy (% of GDP) and ores and metals exports (% of merchandise exports). These two variables are originally from the World Bank World Development Indicators. The variable that measures the size of the government (which is proxied using the share of government spending as a percentage of GDP) is also taken from the Penn World Table 8.0 produced by Feenstra, Inklaar and Timmer (2015).

Short-term variations in the variables listed above might not measure fundamental changes in the quality of institutions or governments. To circumvent the short term lack of variation in the measures of institutions and to improve the quality of the data and empirical analysis, we use five-year averages to build a panel dataset with eight data points including data for 1975-79, 1980-84, 1985-89, 1990-95, 1995-99, 2000-04, 2005-09, and 2010-2011 (not all variables are available for the same time frame).

3.1. Results

Tables A2 through A4 in the appendix report the estimates of the dynamic system model for alternative specifications. Table A2 reports the results for the baseline model. Table A3 reports the estimates of the model including interaction terms for OECD economies. Table A4 considers a set of additional covariates. All models include time[6] and region dummies and are estimated with a robust covariance matrix.

The robustness of the GMM estimates is subject to several conditions including the validity of the instruments and the nature of the autocorrelation in the disturbances. The estimates reported in Table A2 satisfy the requirements of the Arellano-Bond AR(1) and AR(2) tests. More precisely, we find that the AR(1) correlation is positive and statistically significant, but the AR(2) correlation is not significant at standard levels. In addition, the Sargan and Hansen tests can be applied to examine the validity of the instruments. The results of both tests suggest that the lag-structure and instruments are valid for all regressions reported in Table A2.

The estimates reported in Table A2 show that TFP growth is weakly persistent. In particular, the coefficient on lagged TFP growth is positive and statistically significant and range from 0.18 to 0.25. The point estimate of Model 1 implies an auto-correlation of 0.24, that is, about one quarter of a lagged TFP growth shock is transmitted to current

[6] According to Roodman (2009) p.110, “It is almost always wise to include time dummies to remove universal time-related shocks from the errors.”

TFP growth. It is worth noting that while the analysis from Section 3 provides evidence that the relative TFP level is highly persistent, regression analysis indicates that – controlling for quality of institutions and other covariates – the TFP growth rate is significantly less persistent, and thus, responsive to the economic and institutional environment. This finding is of significance because it indicates that if a TFP-disadvantaged economy manages to improve its institutional and economic environment, it could experience faster TFP growth rates.

The size of the government matters. The coefficients on the size of the government are negative and statistically significant in all specifications. This finding suggests that a large government might create disincentives and inefficiencies that hinder TFP growth. Columns 1 through 4 of Table A2 show that the coefficients on globalization are positive and statistically significant in all regressions and that the result is not sensitive to model specification. Hence, globalization (or openness) positively affects TFP growth. Columns 5 through 8 report a set of estimates that substitute the globalization index for both merchandise exports as a share of GDP and merchandise imports as a share of GDP. These two variables are used to conform to other studies. The coefficient estimates on merchandise exports as a share of GDP are positive and statistically significant in all regressions. However, the coefficients on merchandise imports as a share of GDP are positive but only marginally significant in columns 7 and 8. Overall, these results imply that openness might work as an important channel for knowledge and technological diffusion, thus stimulating TFP growth. However, an export-oriented economy seems to benefit the most from international economic integration.

The coefficients on all institutions-related variables included in the model are statistically significant in all specifications. This finding suggests that the institutional environment spurs productivity growth. It is unclear, however, if the effect from institutions on productivity takes place only via technological change or only via efficiency of factors of production or both technological progress and efficiency. Further research might disentangle this issue.

It is also worth noting that the coefficients on the constant term are not statistically significant for models 3, 4 and 7 and only marginally significance for models 1, 2, and 5. This finding is consistent with Danquah *et al.* (2012), which finds that country-specific effects are very important to explain TFP growth.

Table A3 reports the estimates including interaction terms of a dummy for OECD countries with all variables considered in the model. This is intended to examine if the results are applicable to both countries in the technological frontier (OECD) and less developed economies. The results are somewhat mixed. Column 1 shows that the coefficient on the interaction term for lagged TFP growth is not statistically significant, which implies that – conditional on the covariates included in the model – the degree of persistence of TFP is the same for both OECD and non-OECD economies. In addition, the impact of globalization/openness is similar for countries in the technological frontier as well as for countries far from the technological frontier. However, the estimates imply that there are notable differences in the effects of other covariates. First, the coefficient on the interaction term for government size (Column 2) is positive and statistically significant. This implies that while a large government seems to hinder TFP growth across non-OECD countries, the negative effect from government size on TFP growth vanishes for OECD economies. Finally, the coefficient on the interaction term for political constraints is positive and significant, but the coefficient on political constraint itself is no longer significant. In addition, the coefficients on political constraints are also insignificant (Columns 3 and 4). These results together suggest that differences in the quality of governments across OECD and NON-OECD economies are significant and that controlling for government size and openness, political constraints is no longer important to explain TFP growth across non-OECD economies. It is worth noting that the results are very similar using any of the three other measures of institutions (democratization, quality of government, and independent judiciary).

Table A4 reports estimates adding additional regressors to the model. It shows that the results discussed above are robust to adding these new regressors. Moreover, there is no significant effect on TFP growth if an economy is relatively oriented toward production and exports of fuel and mineral (Models 2 and 3). There is also no significant effect from inflation (Model 4), a proxy for macroeconomic volatility. On the other hand, the coefficients on the change in the industry share of GDP and Gini index are negative and statistically significant. This implies that income inequality lowers TFP growth. Contrary to expectations, the estimates imply that a country whose industry share of GDP is increasing experiences lower TFP growth.

4. FINAL REMARKS

This study examines the dynamics of TFP and finds no evidence of global or regional TFP convergence. The analysis, however, indicates clustering that have weak geographic links. The results imply that initial conditions play a fundamental role on the dynamics of TFP: economies that began with lower TFP remained below initially better-positioned economies. Altogether, these findings are not that encouraging for developing economies because they imply that the productivity gap might continue to increase over time and, thus, cause the income gap between advanced economies and developing economies to continue widening.

The regression analysis, however, provides some guidance on how countries away from the technological frontier might slow down or reduce the productivity gap. More precisely, this study provides evidence that the quality of governments and societal arrangements (institutional quality) together with openness are very important determinants of TFP growth. While better institutions promote technological progress and efficiency, globalization affects TFP growth via knowledge and technological diffusion among nations. Thus, TFP growth in developing economies might be stimulated if these countries take steps toward opening their economies and improving the quality of their institutional arrangements.

The findings of this study, however, are subject to some caveats. First, several developing economies were excluded from the analysis due to data limitations. The results, therefore, might not be applicable to some economies. Second, the results suggest that controlling for several measures of institutions, the effect of government size on TFP growth differs significantly across OECD and non-OECD countries. Why a larger government hinders TFP growth in non-OECD economies, but not in OEDC countries? Would this relationship change by considering measures of institutional quality not examined in this study? The answer to these important questions is not addressed here.

APPENDIX

Table A1. List of Countries Included in Regression Analysis

ISO3	Country	Region	ISO3	Country	Region
AUS	Australia	East Asia & Pacific	ARG	Argentina	Latin America & Caribbean
CHN	China		BRB	Barbados	
FJI	Fiji		BOL	Bolivia	
IDN	Indonesia		BRA	Brazil	
JPN	Japan		CHL	Chile	
KOR	Korea		COL	Colombia	
MYS	Malaysia		CRI	Costa Rica	
MNG	Mongolia		DOM	Dominican Republic	
NZL	New Zealand		ECU	Ecuador	
PHL	Philippines		GTM	Guatemala	
SGP	Singapore		HND	Honduras	
THA	Thailand		JAM	Jamaica	
ARM	Armenia	Europe & Central Asia	MEX	Mexico	
AUT	Austria		PAN	Panama	
BEL	Belgium		PRY	Paraguay	
BGR	Bulgaria		PER	Peru	
HRV	Croatia		TTO	Trinidad & Tobago	
CYP	Cyprus		URY	Uruguay	
CZE	Czech Republic		VEN	Venezuela	
DNK	Denmark		BHR	Bahrain	Middle East & North Africa
EST	Estonia		EGY	Egypt	
FIN	Finland		IRN	Iran	
FRA	France		IRQ	Iraq	
DEU	Germany		ISR	Israel	
GRC	Greece		JOR	Jordan	
HUN	Hungary		KWT	Kuwait	
ISL	Iceland		MLT	Malta	
IRL	Ireland		MAR	Morocco	
ITA	Italy		QAT	Qatar	
KAZ	Kazakhstan		SAU	Saudi Arabia	
KGZ	Kyrgyzstan		TUN	Tunisia	
LVA	Latvia		BEN	Benin	Sub-Saharan Africa
LTU	Lithuania		BWA	Botswana	
LUX	Luxembourg		BDI	Burundi	
MDA	Moldova		CMR	Cameroon	
NLD	Netherlands		CIV	Cote d`Ivoire	
NOR	Norway		CAF	Central African Republic	
POL	Poland		GAB	Gabon	
PRT	Portugal		KEN	Kenya	
RUS	Russia		LSO	Lesotho	
SVK	Slovak Republic		MRT	Mauritania	
SVN	Slovenia		MUS	Mauritius	
ESP	Spain		MOZ	Mozambique	
SWE	Sweden		NAM	Namibia	
CHE	Switzerland		NER	Niger	
TJK	Tajikistan		RWA	Rwanda	
TUR	Turkey		SEN	Senegal	
UKR	Ukraine		SLE	Sierra Leone	
GBR	United Kingdom		ZAF	South Africa	
IND	India	South Asia	SWZ	Swaziland	
LKA	Sri Lanka		TZA	Tanzania	
CAN	Canada	North America	TGO	Togo	
USA	United States		ZWE	Zimbabwe	

Table A2. Baseline Model System GMM Estimates Dependent Variable: TFP Growth

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged TFP Growth	0.244***	0.222***	0.252***	0.238***	0.241***	0.226***	0.245***	0.179***
	[6.25]	[5.76]	[5.87]	[4.52]	[6.11]	[5.95]	[5.83]	[3.68]
Lagged Government Share of GDP (%)	-0.00653	-0.0116**	-0.0101*	-0.0126**	-0.0204***	-0.0254***	-0.0217***	-0.0234***
	[-1.35]	[-2.51]	[-1.92]	[-2.23]	[-4.13]	[-5.25]	[-3.09]	[-4.14]
Lagged ΔGlobalization	0.609***	0.626***	0.616***	0.579***				
	[3.76]	[3.87]	[3.73]	[3.08]				
Lagged Political Constraints Index III	0.0182***				0.0127			
	[2.61]				[1.62]			
Lagged Index of Democratization		0.000442***				0.000255**		
		[5.14]				[2.18]		
Lagged Indep. Judiciary			0.00879***				0.00581**	
			[3.24]				[2.14]	
Lagged ICRG- Quality of Government				0.0170**				0.0244**
				[2.12]				[2.56]
Lagged Merchandise Exports (% of GDP)					0.0401**	0.0303*	0.0528***	0.0311**
					[2.28]	[1.68]	[3.10]	[2.09]
Lagged Merchandise Imports (% of GDP)					0.0145	0.000436	0.0284	0.0208
					[0.83]	[0.02]	[1.49]	[1.59]
Constant	-0.0114*	-0.01000*	-0.00719	-0.0103	0.00668*	0.00831**	0.00996***	0.000470
	[-1.89]	[-1.84]	[-1.27]	[-1.60]	[1.73]	[2.54]	[2.70]	[0.09]
Observations	634	634	625	504	834	837	797	511
AR(1)	0	0	0	0	0		0	0
AR(2)	0.822	0.724	0.787	0.638	0.163	0.121	0.172	0.598
Sargan Overid.	0	0	0	0	0	0	0	0
Hansen Overid.	0.820	0.840	0.624	0.181	0.996	0.997	0.899	0.977

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. The numbers in brackets are the t-ratios. All models include time and region dummies and are estimated using lagged instruments for the differenced equation. AR(1) and AR(2) are tests results for auto-regressive processes of order 1 and 2, respectively. The row "Sargan Overid" reports the p-values for the Sargan test of over-identification restrictions. The row "Hansen Overid" reports the p-values for the Hansen test of over-identification restrictions. The covariance matrix of the parameter estimates is calculated using a robust estimator that is consistent in the presence of any pattern of heteroskedasticity and autocorrelation within the panel.

Table A3. System GMM Estimates with OECD Interaction Terms Dependent Variable: TFP Growth

	(1)	(2)	(3)	(4)
Lagged TFP Growth	0.245***	0.229***	0.239***	0.233***
	[5.87]	[5.69]	[6.03]	[5.86]
Lagged Government Share of GDP (%)	-0.00669	-0.0190***	-0.00989*	-0.0161***
	[-1.44]	[-3.08]	[-1.79]	[-2.75]
Lagged ΔGlobalization	0.613***	0.667***	0.573***	0.648***
	[3.79]	[4.05]	[3.39]	[3.95]
Lagged Political Constraints Index III	0.0176***	-0.00773	0.00984	-0.00568
	[2.68]	[-0.69]	[1.16]	[-0.51]
Lagged OECD x TFP Growth	-0.00588			
	[-0.03]			
Lagged OECD x Government Share of GDP (%)		0.0141***		
		[3.79]		
Lagged OECD x Change in Globalization			0.375	
			[1.46]	
Lagged OECD x Political Constraints Index III				0.0293***
				[3.32]
Constant	-0.0111*	0.00102	-0.00701	-0.00105
	[-1.94]	[0.14]	[-1.00]	[-0.14]
Observations	634	634	634	634
AR(1)	0	0	0	0
AR(2)	0.819	0.780	0.840	0.794
Sargan Overid	0	0	0	0
Hansen Overid	0.826	0.821	0.816	0.803

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. The numbers in brackets are the *t*-ratios. All models include time and region dummies and are estimated using lagged instruments for the differenced equation. AR(1) and AR(2) are tests results for auto-regressive processes of order 1 and 2, respectively. The row "Sargan Overid" reports the p-values for the Sargan test of over-identification restrictions. The row "Hansen Overid" reports the p-values for the Hansen test of over-identification restrictions. The covariance matrix of the parameter estimates is calculated using a robust estimator that is consistent in the presence of any pattern of heteroskedasticity and autocorrelation within the panel.

Table A4. System GMM Estimates with Additional Control Variables Dependent Variable: TFP Growth

	(1)	(2)	(3)	(4)	(5)	(6)
Lagged TFP Growth	0.309***	0.234***	0.225***	0.230***	0.168***	0.255***
	[6.28]	[4.81]	[4.63]	[6.11]	[3.51]	[6.41]
Lagged Government Share of GDP (%)	-0.00744	-0.00971**	-0.00833*	-0.0121**	-0.0315***	-0.0116***
	[-1.56]	[-2.17]	[-1.91]	[-2.51]	[-4.93]	[-2.71]
Lagged ΔGlobalization	0.534***	0.605***	0.564***	0.477***	0.550***	0.514***
	[3.19]	[3.65]	[3.52]	[3.32]	[3.55]	[3.63]
Lagged Political Constraints Index III	0.00575	0.00654	0.0151*	0.0166**	-0.0126	0.0136*
	[0.72]	[0.73]	[1.79]	[2.36]	[-1.12]	[1.84]
Lagged Change in Industry share	-0.205**					
	[-2.10]					
Lagged Ores and Metals Exports (% of Merch. Exports)		-0.000279				
		[-1.38]				
Lagged Fuel Exports (% of Merchandise Exports)			0.0000986			
			[1.11]			
Lagged Change in Consumer Price				-0.0395		
				[-1.52]		
Lagged Log Per capita Scientific & techn.journal articles					0.00532***	
					[4.93]	
Lagged Gini Household Gross Income						-0.00108***
						[-4.49]
Constant	-0.00525	-0.00222	-0.00920	-0.00300	0.000931	0.0434***
	[-0.90]	[-0.35]	[-1.45]	[-0.46]	[0.14]	[3.47]
Observations	558	584	577	634	532	540
AR(1)	0	0	0	0	0	0
AR(2)	0.548	0.796	0.749	0.946	0.114	0.191
Sargan Overid	0	0	0	0	0	0
Hansen Overid	0.844	0.804	0.800	1.000	0.883	1.000

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. The numbers in brackets are the t-ratios. All models include time and region dummies and are estimated using lagged instruments for the differenced equation. AR(1) and AR(2) are tests results for auto-regressive processes of order 1 and 2, respectively. The row "Sargan Overid" reports the p-values for the Sargan test of over-identification restrictions. The row "Hansen Overid" reports the p-values for the Hansen test of over-identification restrictions. The covariance matrix of the parameter estimates is calculated using a robust estimator that is consistent in the presence of any pattern of heteroskedasticity and autocorrelation within the panel.

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Received September 14, 2015, Revised May 4, 2016, Accepted August 31, 2016.