Productivity Spillovers in Advanced Economies*

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December 2017
(PRELIMINARY AND INCOMPLETE; PLEASE DO NOT CIRCULATE)

Abstract

This paper estimates spillover effects of the slowdown in TFP growth at the technological frontier to the general TFP slowdown in advanced economies (AEs). For that, it uses data on (cyclically-adjusted) TFP growth rates at country-industry-level for a group of 17 AEs over the period 1970-2010. The findings suggest a combined (intra- and inter-industry) spillover effect of around 0.15-0.2 percentage points in the medium-term for a given 1 percentage point TFP shock in the technological frontier, confirming that its growth slowdown can partly explain the TFP growth slowdown in other AEs.

JEL Classification Numbers: : O47; D24; E6; C33

Keywords: Productivity, Spillovers, Industry-level Total Factor Productivity, Input Utilization

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* We thank Gustavo Adler, Era Dabla-Norris, and Ksenia Koloskova for helpful comments and discussions. We particular grateful to Vikram Haksar and Minsuk Kim for sharing their dataset on TFP levels for our robusteness tests. Sung Jung provided excellent research assistance. All remaining errors are our own. The opinions expressed herein are those of the authors and do not necessarily reflect those of the International Monetary Fund.

I. INTRODUCTION

The TFP growth dynamics in key industries over the last two decades has raised questions about the role of innovation at the technological frontier and spillovers from it both within and across industries. Particularly important has been the developments in the information and communication technology (ICT) industry, after the well-known revolution in the late 1990s and early 2000s.

Figure 1 illustrates such development by displaying the average TFP growth of ICT-intensive and non-ICT-intensive industries for the average country-industry within a group of 17 AEs over time (Panel 1), as well as growth at the TFP frontier for the periods 1980-1990, 1991-2000, and 2001-07 (Panel 2). After the TFP burst of ICT, average productivity in the four ICT-intensive industries[1] slowed down before the GFC. Meanwhile, in non ICT-intensive industries, the pace of productivity growth has been lower and more stable, although there is also evidence of a further slowdown at the frontier (Figure 1, Panel 2).

Furceri et al. (2016) document a TFP growth slowdown across the globe and in particular in advanced economies (AEs) closer to the technological frontier. The same slowdown trend is documented for the U.S. by Fernald (2014a) and Fernald (2014b). Several other authors discuss reasons for this decline in TFP growth at the frontier (e.g., Garcia-Macia, 2015; Garcia-Macia et al., 2016) and its negative implications (Bloom et al., 2013). Among several cyclical and structural factors, one reason put forward for this slowdown has been the spillover effects from a slowdown of TFP growth at the frontier (Furceri et al., 2016).

This paper, thus, attempts to quantify the impact of such headwind. It estimates the spillover effects of the slowdown in TFP growth at the technological frontier to the general TFP slowdown in AEs. We use Furceri et al.'s (2016) data on (cyclically-adjusted) TFP growth rates in a panel set up at country-industry-level for a group of 17 AEs over the period 1970-2010. The empirical analysis further provides a novel methodology to estimate intra- and inter-industry effects of the slowdown at the technological frontier.

Our findings indicate a combined (intra- and inter-industry) spillover effect of around 0.15-0.2 percentage points in the medium-term for a given 1 percentage point TFP shock in the frontier. Such results corroborate the thesis that the slowdown at the frontier can partly explain the TFP growth slowdown in other AEs. The estimations are robust to including additional variables in the analysis or calculating an alternative technological frontier using industry data on TFP levels instead of U.S.' TFP growth rates.

[1] As displayed in Table 1 listing all EU-KLEMs industries in analysis, the four ICT-intensive industries are: (i) electrical and optical equipment (26-27); (ii) publishing, audiovisual and broadcasting activities (58-60); (iii) telecommunications (61); and (iv) IT and other information services (62-63). The charts are robust to weighting the averages to the added value of the different sectors in each country's output.

The paper is structured as follows. Section II describes the empirical strategy used. Section III presents the results, and Section IV performs the robustness checks. Section V concludes the paper and discusses the main policy implications of our findings.

II. Empirical Strategy

A. Data

TFP growth at industry level is obtained from Furceri et al. (2016) and Dabla-Norris and others (2015). They estimate disaggregated technology changes at the industry level (see Appendix A). The industry level datasets used in the estimations of adjusted TFP are the EU KLEMS and the World KLEMS. These datasets are unique since they provide internationally comparable data for industry gross output and inputs of capital, labor, hours worked for [24] industries (see Table 1).[2]

The procedure is applied for a sample of 17 advanced economies[3] over the period 1970-2010 using industry level data from the EU KLEMS and the World KLEMS databases. These datasets provide internationally comparable data for industry gross output and inputs of capital, labor, hours worked for [24] industries (see Table 1).[4] Country-industry data from EU KLEMS and the World KLEMS are also employed in the analysis constructing the TFP frontier using TFP levels (see Dabla-Norris and others),[5] and on the analysis investigating spillover effects via the input channel.

For the analysis testing knowledge diffusion via the trade channel, the dataset used is from IMF (2016). That is a bilateral-sectoral database of trade flows obtained from United Nations Commodity Trade Statistics at the Standard International Trade Classification revision 2, four-digit level. It includes about 780 uniquely identified products and their bilateral trade flows from 1998–2014. To analyze the connection between trade and TFP growth spillovers, those 780 sectoral trade flows are mapped into the 10 nonservices sectors from KLEMs and aggregated accordingly.

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[2] As Table 1 reports on its footnote, some of the sectors have no data available in order to estimate the TFP growth. For some other sectors, the data is only available for a subset of countries (see footnote [2]). All the sectors highlighted are currently excluded from the analysis.

[3] The economies considered are: Australia, Austria, Canada, Denmark, Finland, France, Germany, Greece, Japan, Ireland, Italy, Korea, the Netherlands, Portugal, Spain, the United Kingdom, and the United States. Data availability limitations preclude the analysis for recent years since 2010.

[4] Data on the sectors *Publishing, audiovisual and broadcasting activities* (58-60), *Telecommunications* (61), and *IT and other information services* (62-63), are not available for the following countries: Australia, Canada, Denmark, Greece, Ireland, Korea, and Portugal.

[5] We are thankful to Vikram Haksar and Minsuk Kim for providing the data on TFP levels.

B. Methodology

The empirical methodology follows the approach proposed by Jorda (2005) and expanded by Teulings and Zubanov (2014), by tracing out the evolution of TFP in the aftermath of TFP shocks at the frontier through the local projection method (LPM). As argued by Stock and Watson (2007) and Auerbach and Gorodnichenko (2013), among others, this approach provides a flexible alternative that does not impose dynamic restrictions embedded in vector autoregressive (autoregressive distributed lag) estimations.

Given the data availability at the country-industry level, the analysis initially focuses on shocks in US industries, assuming that they constitute the TFP frontier. This assumption is relaxed later, using data on TFP levels obtained from Dabla-Norris and others (2015) to construct a time-varying TFP frontier (maximum levels of TFP) at country-industry level for a subset of 11 countries and 18 industries (see Table 2).

Spillover effects are initially estimated at the aggregated country level. At the industry level, spillover effects can operate within each industry (through diffusion via competition or learning) or across industries (input channel). The corresponding econometric specifications used to estimate these TFP spillovers effects are described below.

Spillover effects of US TFP growth at aggregate (country) level

The first econometric specification aims to establish whether TFP shocks in the United States materially affect TFP in other advanced economies. The analysis follows the approach proposed by Jorda (2005) and expanded by Teulings and Zubanov (2014), by tracing out the evolution of TFP in advanced economies in the aftermath of U.S. TFP shock. This approach has been advocated by Stock and Watson (2007) and Auerbach and Gorodnichenko (2013), among others, as a flexible alternative that does not impose dynamic restrictions embedded in vector autoregression (autoregressive distributed lag) specifications. Specifically, the method consists of estimating separate regressions of TFP growth at different horizons k:

$$tfp_{i,t+k} - tfp_{i,t-1} = \alpha_i + \beta_k dtfp_{US,t} + \delta(L)dtfp_{i,t} + \sum_{h=1}^{k} \theta_j dtfp_{US,t+h} + \varphi(L)dtfp_{US,t} + \varepsilon_{i,t}, \quad (1)$$

in which tfp is the log of adjusted TFP (corresponding to the line TOT in Table 1); α_i are country fixed effects;[6] and $dtfp_{US}$ is the U.S. adjusted TFP growth. The specification includes lags of TFP growth in the U.S. and the other countries. Since variables affecting

[6] Notice that time fixed effects are not included given that they would cause multicollinearity in the estimation at the aggregate level: the same US TFP growth rates are applied to all countries and so these repeated growth rates for all countries in a particular year would be collinear to a time dummy capturing fixed effects.

TFP growth are typically serially correlated, the inclusion of lags allows controlling for short-term factors that affect the short-term response of TFP growth in a particular country i. In our baseline specification, we usually choose 2 lags to estimate those short-term effects. In addition, and following Teulings and Zubanov (2014), we also include the forward leads of U.S. utilization-adjusted TFP growth between time 0 and the end of the forecast horizon to correct the impulse response bias inherent in local projection methods. We further include two lags of U.S. utilization-adjusted TFP growth.

The model is estimated for each k. Impulse response functions are computed directly using the estimated coefficients β_k. That coefficient measures the spillover effect of a 1 percent change in the U.S. aggregated TFP growth adjusted for unobserved input utilization. The 90-percent confidence bands associated with the estimated impulse response functions are obtained using the estimated standard deviations of the coefficients β_k. Equation (1) is estimated using heteroskedasticity- and autocorrelation-robust standard errors.

A possible concern in the estimation of equation (1) is reverse causality, because changes in TFP in other countries may affect U.S. TFP. However, as one of our robustness check, we include average changes in TFP in other AEs following a U.S. TFP shock as one of our controls in the estimation of (1).

Intra-industry spillovers from US TFP shocks

A second specification investigates the intra-industry spillover effects of US TFP level shocks in an industry on the same corresponding industry in the other AEs. Those effects are estimated as follows:

$$tfp_{i,j,t+k} - tfp_{i,j,t-1} = \alpha_{i,j} + \gamma_t + \beta_k dtfp_{US,j,t} + \delta(L) dtfp_{i,j,t} + \sum_{h=1}^{k} \theta_j dtfp_{US,j,t+h} + \varphi(L) dtfp_{US,j,t} + \varepsilon_{i,t}, \quad (2)$$

where j is a particular industry among the [24] industries listed in Table 1; $\alpha_{i,j}$ are now country-industry fixed effects; γ_t are time fixed effects; and $dtfp_{US,j,t}$ is the U.S. adjusted TFP growth at industry level. The model is again estimated for each k. Impulse response functions are computed using the estimated coefficients β_k, which here measures the direct spillover effect of a 1 percent change in a particular industry-level U.S. adjusted TFP growth.

Inter-industry spillovers from US TFP shocks

Instead of analyzing the intra-industry spillover effect of shock in TFP growth in a particular industry in other AEs, the third specification explores the input channel by exploiting differences across countries and industries in the extent to which inputs from the US are used in the production process. The specification is as follows:

$$tfp_{i,j,t+k} - tfp_{i,j,t-1} = \alpha_i + \gamma_t + \beta_k \bar{X}_{i-US} dtfp_{US,s,t} + \delta(L) dtfp_{i,j,t} + \sum_{h=1}^{k} \theta_j dtfp_{US,s,t+H} + \varphi(L) dtfp_{US,s,t} + \varepsilon_{i,t}, \quad (3)$$

in which j is a downstream industry in the advanced economies; s is the upstream industry in the US; and $\bar{X}_{i-US}$ denotes different weighting matrices representing country-specific characteristics, such as through the use of inputs in a particular industry with a TFP growth shock, that have been typically found in the literature to be key transmission channels for knowledge spillovers (see, for example, Coe and Helpman 1995; Coe, Helpman, and Hoffmaister 2009; Rondeau and Pommier 2012), including in the trade literature where TFP gains from imported input variety and quality have been highlighted theoretically (e.g. Grossman and Helpman, 1991; Markusen, 1989) and identified empirically (Kasahara and Rodrigue, 2008; Topalova and Khandelwal, 2011; Amiti and Konings, 2013; Halpern et al., 2015); Ahn and others, 2016.[7]

Inter-industry spillover from US TFP shocks via the input channel

One potential transmission channel for the US TFP level shocks at industry level is through the importance of each US industry as an input for a particular sector in each other AE. To test for that channel, we use information from input-output matrices and calculate the weights of US inputs in each downstream sector in each country (backward weights) for the year 2005, to minimize any endogeneity issues, excluding the use of the US inputs in the US economy itself:

$$\omega_{i,j,s,2005} = \frac{Input\ Industry_{i,j,s,2005}}{\sum_{j=1,i=1}^{J,N} Input\ Industry_{i,j,s,2005}}, \quad (4)$$

where ω is an element for each j downstream industry in the other AEs and upstream industry s in the US in a $NJ \times S$ weighing matrix $\Omega_{NJ \times S}$. $N = 16$ is the total number of advanced economies (apart from the US), $J = 24$ is the total number of downstream industries in those countries and $S = [1,24]$ is the number of upstream industries in the US investigated in the analysis. In the simplest version, only one upstream US industry $(S = 1)$ is investigated (say, the electrical and optical equipment industry), whereas in the most complete version all downstream sectors with available data $(S = J = 24)$ are investigated. In any of those cases, by construction, the sum of the elements of $\Omega_{NJ \times S}$ equals to 1.

[7] Other possibilities country's relative distance from the technology frontier—defined as the gap between the country's total factor productivity and that of the United States—and trade and financial openness vis-à-vis the United States.

We then multiply this weighting vector by the US productivity value for the upstream US industries investigated in each year to obtain the weighted average productivity growth in each sector for the US as represented by (3):

$$\forall t: \bar{X}_{i-US} dtfp_{US,s,t} = \begin{bmatrix} \omega_{AUS,1,s,2005} & \cdots & \omega_{AUS,1,S,2005} \\ \vdots & \cdots & \vdots \\ \omega_{AUS,24,s,2005} & \cdots & \omega_{AUS,24,S,2005} \\ \vdots & \ddots & \vdots \\ \omega_{UK,1,s,2005} & \cdots & \omega_{UK,1,S,2005} \\ \vdots & \cdots & \vdots \\ \omega_{UK,24,s,2005} & \cdots & \omega_{UK,24,S,2005} \end{bmatrix}_{NJ\times S} \times \begin{bmatrix} dtfp_{US,s,t} \\ \vdots \\ dtfp_{US,S,t} \end{bmatrix}_{S\times 1} \quad (5)$$

This provides a vector $NJ\times 1$ of values of weighted average TFP growth in the US for a set S of industries per year.[8]

Robustness check: Intra-industry spillover effects via the trade channel

As a robustness check to the intra-industry (competition) spillover, the second transmission channel for the US TFP growth shocks at industry level checks more precisely the importance of each US industry as a competitor for a particular sector in each other AE. For that, we use information from bilateral trade in goods coming from UN Comtrade (see WEO Oct. 2016) and calculate the share of US exports to the total (external and domestic) production of each sector in each country (backward weights) for the year 2005, excluding the use of the US inputs in the US economy itself:

$$\rho_{i,j,s,2005} = \frac{Goods\ Trade\ Industry_{i,j,s,2005}}{\sum_{j=1,i=1}^{J,N} Goods\ Trade\ Industry_{i,j,s,2005}}, \quad (6)$$

where ρ is a weighing element for each j upstream industry in the other AEs and downstream industry s in the US in a $NJ\times S$ weighing matrix $\Omega_{NJ\times S}$. $N = 16$ is the total number of advanced economies (apart from the US), $J = [10]$ is the total number of upstream goods[9] industries in those countries and $S = [1, [10]]$ is the number of downstream industries in the US investigated in the analysis. In the simplest version, only one downstream US industry

[8] Two versions of the weighing matrix $\Omega_{NJ\times S}$ are employed in the analysis. The first (baseline) eliminates inputs from an upstream industry in the US used in a same downstream industry in the other AE. This means that the diagonals of the weighing matrix $\Omega_{NJ\times S}$ are zero, guaranteeing that the analysis is purely inter-industrial. The second version of that matrix includes non-zero values for those diagonals. The results (not-shown here and available upon request) indicate very robust and similar effects using both versions of the matrix.

[9] UN Comtrade only provides data for goods trade. Therefore, the number of industries covered in this analysis is only a subset ([10] industries) of the previous analysis on the direct (industry-to-industry) and input channel spillovers.

($S = 1$) is investigated (say, the electrical and optical equipment industry), whereas in the most complete version all downstream sectors with available data ($S = J = [10]$) are investigated. In any of those cases, by construction, the sum of the elements of $\Omega_{NJ\times S}$ equals to 1.

We then multiply this weighting vector by the US productivity value for the downstream US industries investigated in each year to obtain the weighted average productivity growth in each sector for the US as represented by (3):

$$\forall t{:}\, \bar{X}_{i-US} dtfp_{US,s,t} = \begin{bmatrix} \rho_{AUS,1,s,2005} & \cdots & \rho_{AUS,1,S,2005} \\ \vdots & \cdots & \vdots \\ \rho_{AUS,24,s,2005} & \cdots & \rho_{AUS,24,S,2005} \\ \vdots & \ddots & \vdots \\ \rho_{UK,1,s,2005} & \cdots & \rho_{UK,1,S,2005} \\ \vdots & \cdots & \vdots \\ \rho_{UK,24,s,2005} & \cdots & \rho_{UK,24,S,2005} \end{bmatrix}_{NJ\times S} \times \begin{bmatrix} dtfp_{US,s,t} \\ \vdots \\ dtfp_{US,S,t} \end{bmatrix}_{S\times 1} \qquad (7)$$

This provides a vector $NJ{\times}1$ of values of weighted average TFP growth in the US for a set S of industries per year.

III. RESULTS

A. Macro TFP growth values

Figure [2] displays the results of the four analysis above. Overall, the findings indicate that from a historical perspective a slowdown in the US TPF has had a gradual, increasing, and significant spillover effects on TFP levels of other AEs.

The results from estimating the impact of U.S. TFP at macro level on TFP in other economies using equation (1) are presented in Panel 1 of Figure [2]. Its specification includes two lags of the dependent and shocked variable. It also excludes outliers by eliminating observations above the top and bottom first percentiles, even though the results are robust to not trimming the data or using one lag instead of two in the specification.[10] The figure presents the estimated spillover effect and the associated 90 percent confidence bands (dashed lines).

The impulse response in that panel are significant up to the third period after the TFP growth shock in the US. It suggests that a one percent change in the aggregated U.S. total factor productivity growth adjusted for unobserved input utilization leads on average to a 0.06

[10] See Appendix [B] for the underlying series and their statistics in the analysis as well as some robustness check.

percentage point increase in TFP growth in other AEs in the short term—1 year after the shock—and by about 0.6 percentage points in the medium term—5 years after the shock.[11]

B. Intra-industry spillover effects from the US industries

The use of sectoral data provides more variability about the potential spillover effects of US TFP growth shocks to other AEs. They also provide more degrees of freedom to the estimations of the coefficients, improving the power of the estimation. Hence, as in the methodological section, we start by estimating the intra-industry (direct) spillover effects as presented in Equation (2). The impulse response functions (IRFs) related to those estimations are displayed in Panel 2 of Figure 2.

The IRF shows that the average TFP spillovers of a particular industry in the US in the same industry for another AE is relatively small, even though the estimation provides lower standard errors and, therefore, narrower and more significant confidence bands. In particular, the IRFs in Figure 2 Panel 2 suggest that a one percentage change on the US TFP level in all industries lead on average to a 0.01 percentage point increase in TFP level in other AEs in the short term—1 year after the shock—and by about 0.08 percentage points for each 1 percentage point US TFP level shock in the medium term—5 years after the shock.[12]

C. Inter-Industry spillover effects via US input utilization

For the input channel, the analysis estimating Equation (3) using the weighting scheme from Equations 4 and 5 is displayed by Panel 3 of Figure 2. The IRF in panel 3 indicates that an one percentage change on the US TFP level in all industries is on average associated with an approximately 0.1 percentage point increase in TFP in other AEs in the medium term through this input channel.

As an additional exercise, the effects of high- and low input intensity are also investigated. To understand how large the spillover effects from TFP level shocks in the US to high-input-intense sectors are, the impulse response presented in Panel 3 of Figure 2 are rescaled by the ratio of the 75th percentile (larger or equal) value of the input-intensity weight distribution

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[11] A possible concern regarding our result is that global factors may simultaneously affect TFP growth in the United States and in the rest of advanced economies. To address this issue and as a robustness check, we include as a control variable in equation (1) the average world (excluding the U.S.) TFP growth. The results are qualitatively similar and not statistically different from those shown in Figure 1 (see Appendix B).

[12] The estimations again use a two-lag structure and exclude outliers at the top and bottom 5th percentile of the distribution of the TFP growth level at country-year-sector level for the advanced economies (excluding US). See Appendix C for the full set of results and some robustness checks.

divided by average value of the input-intensity weight distribution.[13] Likewise, to understand how small the spillover effects from TFP level shocks in the US to low-input-intense sectors are, the impulse response presented in Figure X are rescaled by the ratio of the 25th percentile (lower than) value of the input-intensity weight distribution divided by average value of the input-intensity weight distribution.

The IRFs obtained by using this rescaling method are presented in Panel 1 of Figure 3. They suggest that TFP spillovers are significantly larger for countries in which the US sectoral inputs contribute more to their sectoral outputs. In particular, the increase in TFP level in a country that is relatively strongly linked with the United States via the inputs the US provides to the country (at the 75th percentile) is about six times larger at 0.23 percentage points higher than in a country that has relatively low linkages (at the 25th percentile).

Taken together, the average results for the intra- and inter-industry spillovers indicate a combined spillover effect of around 0.2 percentage points in the medium-term for a given 1 percentage point TFP level shock in the US. This suggests that the observed slowdown in US TFP growth in industries where the US is the technological leader can partly explain a the TFP growth slowdown in other AEs (Figure 3, Panel 1).

IV. ADDITIONAL RESULTS AND ROBUSTNESS CHECKS

A. To be completed [Intra-Industry Spillovers: Trade Channel]

For the trade channel, the analysis uses UN Comtrade bilateral trade data at industry level and estimates Equation (3) using the weighting scheme from Equations (6) and (7) is displayed by Panel 4 of Figure X. Thus, it uses an interaction term in (3) of the US TFP growth rates at industry-level with the share of exports from the US (in 2005) at the same industry to the total output (total imports from all other countries plus domestic production) of each AE in that industry. The IRF in panel 4 indicates that a 1 percentage change on the US TFP growth rates at industry is on average associated with a 0.23 percentage point increase in TFP growth in other AEs in the medium-term through the trade (competition) channel.

We also perform the analysis of the effects of high- and low trade intensity of a particular goods industry with the US. The IRF presented in Panel 4 of Figure X is thus rescaled by the ratio of the 75th percentile (larger or equal) value of the trade-intensity weight distribution

[13] More specifically, this is done by using the same coefficient β_k estimated using Equation (2), but rescaling it by the ratio between the 75th (or 25th) percentile and the average value of the of the US input intensity across its whole country-industry-year distribution.

divided by average value of the trade-intensity weight distribution. Likewise, to understand how small the spillover effects from TFP growth shocks in the US to low-trade-intense sectors are, the IRF presented in Figure X is rescaled by the ratio of the 25th percentile value of the trade-intensity weight distribution divided by average value of the trade-intensity weight distribution.

Given the low number of goods sectors covered in this exercise and the resulting low variability in the data, the IRF presented in Figure X (panel 2) are not statistically significantly different from each other, pointing to just a slight higher spillover effect of highly-traded vis-à-vis low-traded sectors with the US in this exercise.

B. World Averages and Banking Crises

A possible concern in the estimation of Equation (2) is reverse causality and omitted variable bias. That is because changes in TFP in other countries may affect U.S. TFP, or respond to common technological shocks. Thus, a robustness check is implemented by adding the average changes in TFP growth in other AEs following a U.S. TFP shock as a control in the estimation of (2).

Figure [4] displays the IRFs for this robustness exercise, which indicate that the estimated medium-term spillover effects are robust to this robustness check, and only slightly smaller than the combined effect of 0.2 percentage points found in the previous analysis.

C. Frontier Analysis

An additional refinement entails relaxing the assumption that the US is the technological frontier across sectors. This is done by focus on TFP shocks from a time-varying industry frontier. In principle, spillovers via knowledge diffusion should come from countries with the highest productivity in a particular industry. However, while this is conceptually a clearer exercise than the baseline one presented above, it requires level (rather than growth) TFP data that are more scarce and subject to methodological limitations.[14]

[CHART WITH THE COUNTRY-INDUSTRIES AT THE FRONTIER]

The time-varying frontier is calculated by using the TFP levels from Dabla-Norris et al (2015) and finding the maximum TFP level for each available industry and year across the 11 countries (with available TFP level data). Once these country-industries at the frontier are identified for each year, their TFP growth rates are replaced in the estimation of (1) and (2) ,

[14] EU-KLEMs provides data on TFP level only for some years (particularly 1996), which were projected forward via an inventory method using TFP growth rates more broadly available. See Table 2 for the list of industries containing information on TFP levels and the Technical Appendix 3 of Dabla-Norris and others (2015) for more details in the construction of this variable.

while making sure that the particular country in the frontier is not included in the left-hand side of those equations and that the U.S. is inserted in the left-hand side when not identified as being in the frontier.

Figure [5] shows the estimated IRFs for both equations over the period 1985-2007. For both the intra- and inter-industry spillover analysis, the IRFs are significant in medium term, indicating the previous findings are robust to this refinement. A one percent frontier TFP shock leads, on average, to a 0.05 percentage point increase in TFP in other AEs in the short term—1 year after the shock—and by about 0.1 percentage points in the medium term—5 years after the shock. For the inter-industry analysis via the input channel, the estimated spillover effects in this refined exercise are slightly lower than in the baseline estimation: a one percent frontier TFP shock leads, on average, to a 0.04 percentage point increase in TFP in other AEs in the short term—1 year after the shock—and by about 0.06 percentage points in the medium term—5 years after the shock.

V. Conclusion

This paper estimates intra- and inter-industrial spillover effects from a slowdown of TFP growth at the frontier to TFP in other advanced economies.

The findings indicate a combined (intra- and inter-industry) spillover effect of around 0.15-0.2 percentage points in the medium-term for a given 1 percentage point TFP shock in the frontier. This suggests that the observed slowdown in TFP growth in the US, and at the industry-specific technological frontier more broadly, can partly explain a the TFP growth slowdown in other advanced economies. These results are robust to including additional variables in the analysis or calculating an alternative technological frontier using industry data on TFP levels instead of U.S.' TFP growth rates.

This suggests that the observed slowdown in TFP growth at the frontier may indeed be affecting TFP growth in other AEs through lower knowledge diffusion and competition effects. In a scenario of low growth in the medium-term for AEs, such finding calls for an even bigger boost in investment, R&D and innovation in those countries in order to counterpoise the headwinds coming from the technological frontier. Such spillovers seem also to be hindering the convergence process of other AEs to the technological frontier…

Tables and Figures

Table 1 List of Industries Used in the Estimation of TFP Growth

Industry Description	Industry Code
AGGREGATED INDUSTRIES	TOT
ICT GOODS AND SERVICES	ELECOM
Electrical and optical equipment	26-27
Publishing, audiovisual and broadcasting activities	58-60
Telecommunications	61
IT and other information services	62-63
TOTAL MANUFACTURING, EXCLUDING ELECTRICAL	MexElec
Food products, beverages and tobacco	10-12
Textiles, wearing apparel, leather and related prodcuts	13-15
Other manufacturing; repair and installation of machinery and equipment	31-33
Wood and paper products; printing and reproduction of recorded media	16-18
Coke and refined petroleum products	19
Chemicals and chemical products	20-21
Rubber and plastics products, and other non-metallic mineral products	22-23
Basic metals and fabricated metal products, except machinery and equipment	24-25
Machinery and equipment n.e.c.	28
Transport equipment	29-30
Agriculture, forestry and fishing	A
Mining and quarrying	B
Electricity, gas and water supply	D-E
Construction	F
DISTRIBUTION	DISTR
Wholesale and retail trade and repair of motor vehicles and motorcycles	45
Wholesale trade, except of motor vehicles and motorcycles	46
Retail trade, except of motor vehicles and motorcycles	47
Transport and storage	49-52
Postal and courier activities	53
FINANCE AND BUSINESS, EXCEPT REAL ESTATE	FINBU
Financial and insurance activities	K
Professional, scientific, technical, administrative and support service activities	M-N
PERSONAL SERVICES	PERS
Accommodation and food service activities	I
Arts, entertainment and recreation	R
Other service activities	S
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	T
NON-MARKET SERVICES	NONMAR
Real estate activities	L
Public admin, education and health	OtQ
Public administration and defence; compulsory social security	O
Education	P
Health and social work	Q

Source: EU-KLEMs.

Note: Industries classified using ISIC-revision 4.

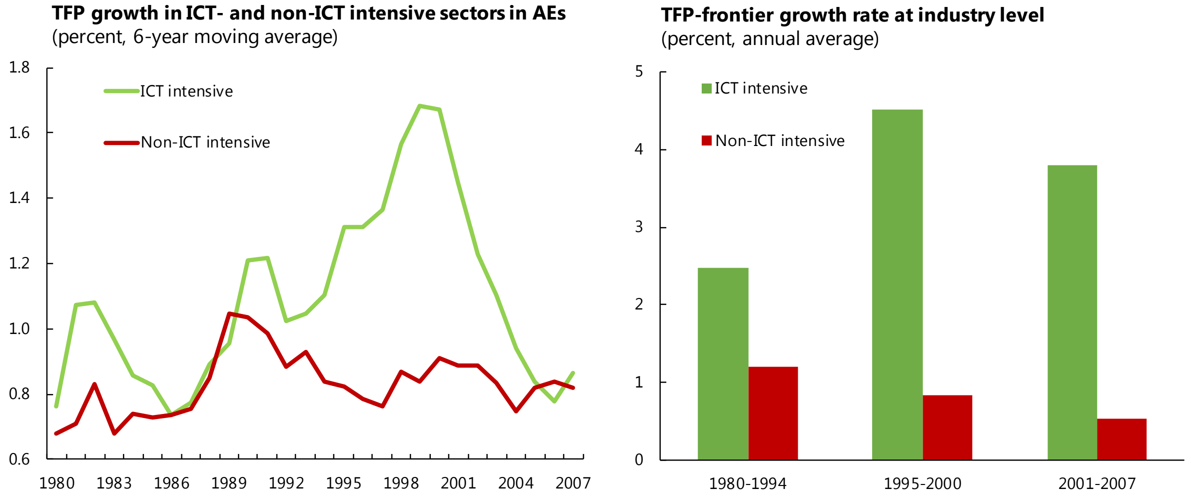
Table 2 List of Industries with Information on TFP Levels, 1970-2007

Industry Description	Industry Code
Accommodation and food service activities	I
Agriculture, forestry and fishing	A
Basic metals and fabricated metal products, except machinery and equipment	24-25
Chemicals and chemical products	20-21
Electrical and optical equipment	26-27
Electricity, gas and water supply	D-E
Financial and insurance activities	K
Food products, beverages and tobacco	10-12
Machinery and equipment n.e.c.	28
Mining and quarrying	B
Other manufacturing; repair and installation of machinery and equipment	31-33
Real estate activities	L
Rubber and plastics products, and other non-metallic mineral products	22-23
Textiles, wearing apparel, leather and related prodcuts	13-15
Transport and storage	49-52
Transport equipment	29-30
Wood and paper products; printing and reproduction of recorded media	16-18

Source: EU-KLEMs

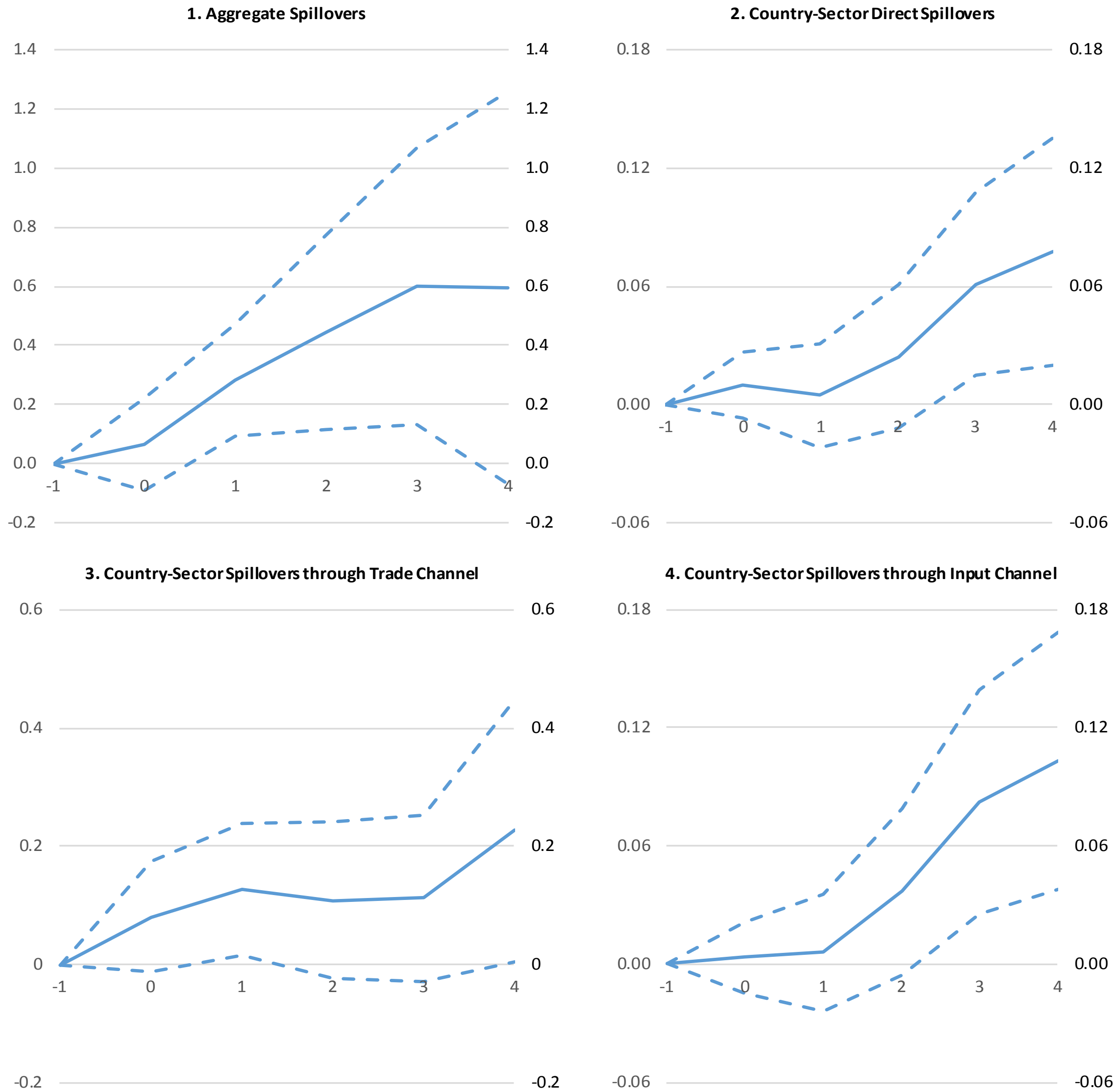
Note: Industries classified using ISIC-revision 4. Data available for the following countries: Australia, Austria, Denmark, Germany, Italy, Japan, Netherlands, Spain, Sweden, United Kingdom and United States.

Figure 1. TFP Growth in ICT- and Non-ICT-intensive Sectors in Advanced Economies



Source: Furceri, Kiliç Çelik, and Schnucker (2016); Dabla-Norris and others (2015), EU-KLEMs Database; and staff estimations
Note: Top and bottom deciles of the TFP-level and top and bottom 5th percentiles of the adjusted-TFP growth distributions across country-industries are excluded as outlier treatment. TFP frontier in Panel B is defined as the average of the three highest TFP levels across countries for each industry and year.

Figure 2. Spillover of a Slowdown in the US TFP growth, 1970-2010

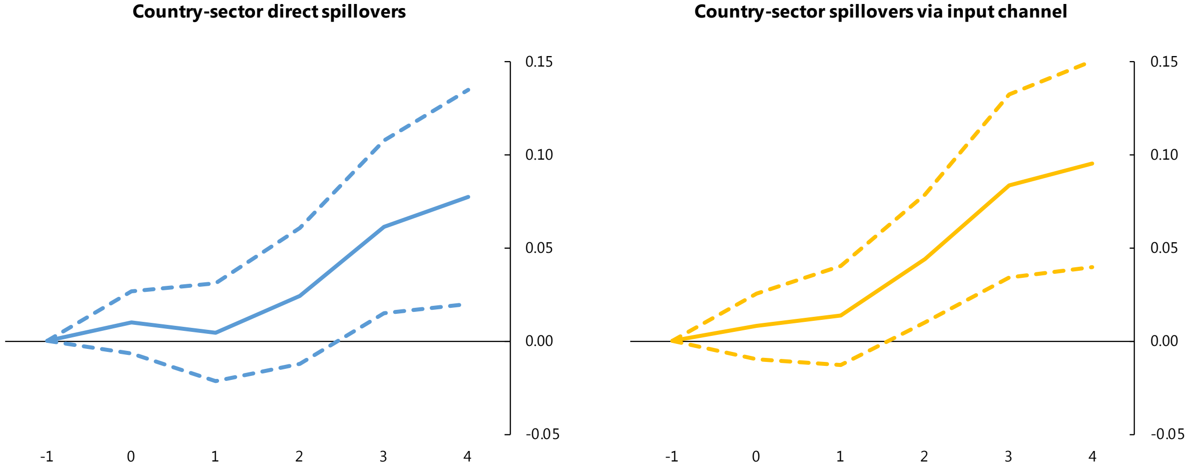


Source: EU-Klems database; UN-Comtrade; and staff estimations.

Notes: Aggregate spillover estimated using country-fixed-effects and excluding observations at the top and bottom first percentiles as outlier treatment.

Country-sector spillovers estimated using country-sector- and year-fixed-effects. Estimations of direct and input channel spillovers exclude top and bottom fifth percentiles as outlier treatment.

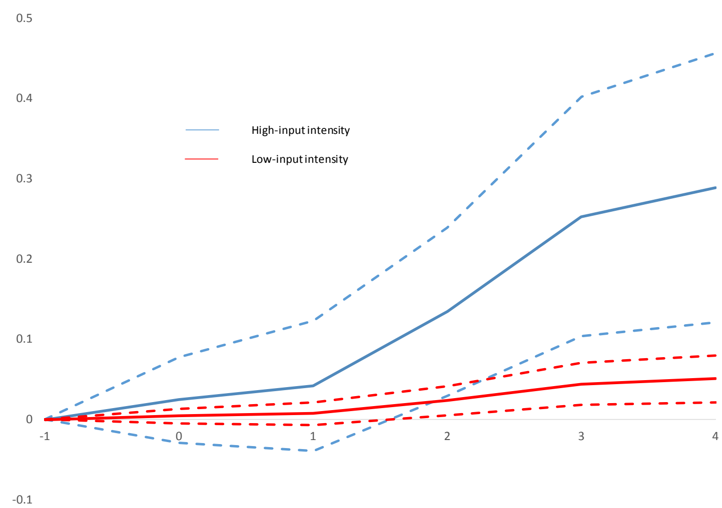
Figure 2. Spillover from a 1 percentage change in U.S. TFP growth to other AEs
(percentage points; years on x-axis)



Source: Furceri, Kiliç Çelik, and Schnucker (2016); EU-KLEMs Database; and staff estimations
Note: Estimates of the intra-industry spillover from U.S. TFP growth shocks to other AEs for different horizons obtained via local projections method. The input channel is estimated by interacting U.S. TFP growth shocks with a weighting matrix capturing the importance of each US industry as an input for a particular industry in each other AE. Estimations include country-sector- and year-fixed-effects and exclude top and bottom fifth percentiles of U.S. TFP growth sample distribution at industry level as outlier treatment. Dashed lines denote 90 percent confidence intervals.

Figure 3. Inter-Industry spillovers from U.S. TFP shocks in other AEs via input channel (high- and low intensity)

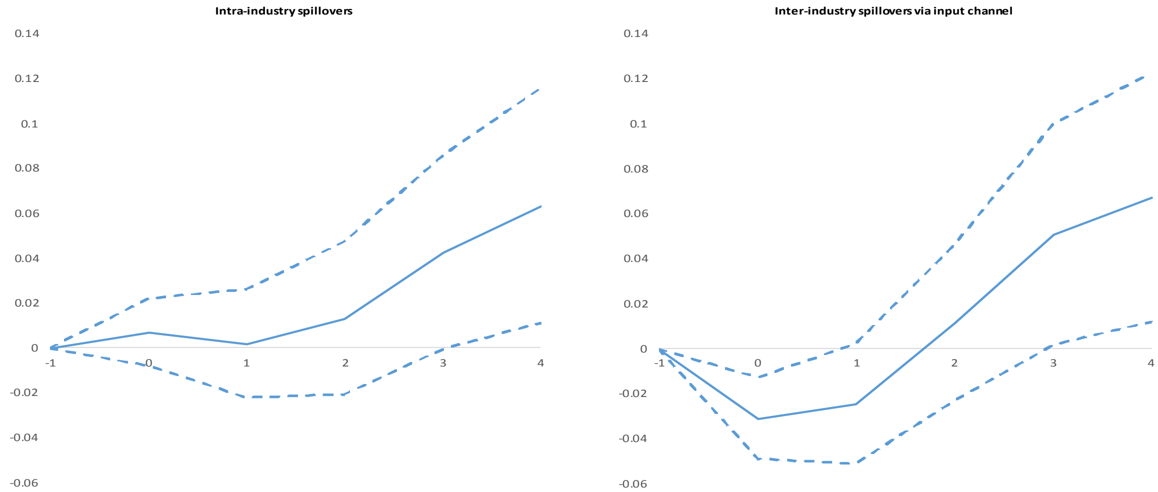
(percentage points; years on x-axis)



Source: Furceri, Kiliç Çelik, and Schnucker (2016); EU-KLEMs Database; and staff estimations

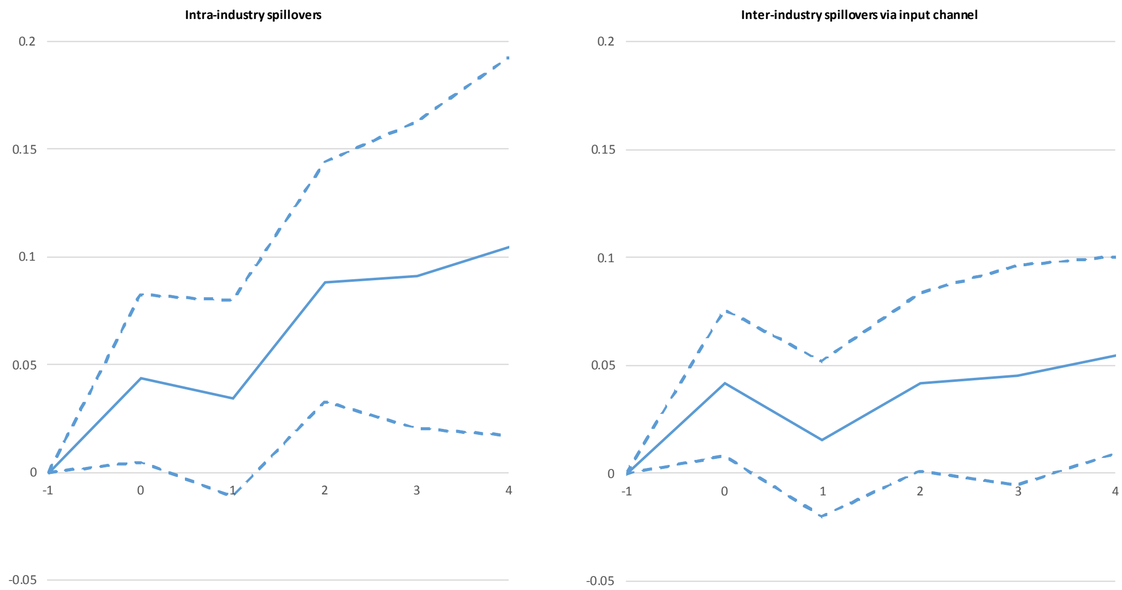
Note: Input channel is estimated by interacting U.S. TFP growth shocks with a weighting matrix capturing the importance of each US industry as an input for a particular industry in each other AE. High- and low intensity correspond to the 75th and 25th percentiles of the cross-country-industry distribution of the input weights in the sample. Estimations include country-sector- and year-fixed-effects and exclude top and bottom fifth percentiles of U.S. TFP growth sample distribution at industry level as outlier treatment. Dashed lines denote 90 percent confidence intervals.

Figure 4. Spillover from U.S. TFP growth shocks controlling for average changes in other AEs, 1970-2010



Sources: Furceri, Kilic Celik, Schunuker (2016), EU-KLEMS and IMF staff estimations.
Note: Estimates of the intra-industry relationship between shocks in the U.S. TFP growth and TFP growth at the country-industry level in other AEs for different horizons are obtained via local projection method. The input channel is estimated by interacting U.S. TFP growth shocks with a weighting matrix capturing the importance of each U.S. industry as an input for a particular industry in each other AE. Estimations include country-industry- and year-fixed effects and exclude top and bottom fifth percentiles of U.S. TFP growth sample distribution at industry level as outlier treatment. Dashed lines denote 90 percent confidence intervals.

Figure 5. Spillover from TFP-Frontier growth shocks, 1985-2007



Sources: Furceri, Kilic Celik, Schunuker (2016), EU-KLEMS and IMF staff estimations.
Note: Estimates of the intra-industry relationship between shocks in the U.S. TFP growth and TFP growth at the country-industry level in other AEs for different horizons are obtained via local projection method. The input channel is estimated by interacting U.S. TFP growth shocks with a weighting matrix capturing the importance of each U.S. industry as an input for a particular industry in each other AE. Estimations include country-industry- and year-fixed effects and exclude top and bottom fifth percentiles of U.S. TFP growth sample distribution at industry level as outlier treatment. Dashed lines denote 90 percent confidence intervals. The inter-industry spillovers are estimated with one lag instead of two.

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APPENDIX A: ESTIMATING UTILIZATION-ADJUSTED TFP GROWTH

We use the estimations from Furceri, Kilic-Celik, and Schnucker (2016), which follows the procedure proposed by Basu, Fernald, and Kimball (2006) and Fernald (2014a, 2014b). Those authors construct such a series by controlling for time-varying unobserved utilization in capital and labor and aggregation effects.

Correcting for unobserved input utilization is essential to properly evaluating the evolution of aggregate TFP growth during the business cycle, and in particular during periods of booms and recessions. Similarly, controlling for aggregation effects is important to correct for sectoral heterogeneity, since the aggregate Solow residual, typically used as a proxy for TFP growth, depends on which sectors change input use the most during the business cycle (Basu and Fernald, 1997; Basu and Kimball, 1997; and Hall 1990).

Following Hall (1990) and Basu and Fernald (2001), Furceri et al (2016) assume cost minimization and relate output growth to the growth of the inputs and compute the utilization-adjusted TFP growth as the difference between the aggregate TFP (Solow residual) and aggregate utilization of factors.