Understanding Global Productivity Cycles

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Abstract. This paper analyzes the common drivers of sectoral productivity cycles in 13 advanced economies across 15 sectors during the past three decades. We estimate a dynamic factor model that decomposes fluctuations in sectoral productivity into four distinct components: (i) a global factor, which captures fluctuations common to all countries and sectors; (ii) sector-specific factors, which capture fluctuations common across countries within each sector; (iii) country-specific factors, which capture fluctuations common across sectors within each country; and (iv) idiosyncratic factors, which are specific to each sector in each country. We report two major results. First, the common factors (global and sector-specific) constitute an important source of variation in sectoral productivity cycles, providing evidence for a global productivity cycle. Specifically, the global and sector-specific factors together account for about one-fourth of the variation in sectoral productivity cycles, ranging from 13 percent in the United States to 35 percent in France. Second, the global and sector-specific components of productivity fluctuations play a significant role in driving business cycle fluctuations. They, on average, account for about 42 percent of sectoral output volatility, explaining from 30 percent of the forecast error variance in Denmark to 56 percent in Germany for the one-year horizon. These findings are consistent with the predictions of a dynamic multi-country multi-sector general equilibrium model with productivity process comprising a global, sector-specific, and country-specific factors, that is calibrated to match the bilateral input-output trade linkages of 13 countries and 15 sectors.

Keywords: productivity, global, sector-specific, dynamic factor model, dynamic multi-country multi-sector general equilibrium model.

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1. Introduction

Idiosyncratic disturbances specific to sectors have the potential to generate business cycles (Horvath, 2000; Foerster et al., 2011; Atalay, 2017; Li and Martin, 2019; Lehn and Winberry, 2022).[1] Additionally, a few seminal studies have examined the role of sector-specific factors that transcend across national boundaries in explaining business cycles (Stockman, 1988; Norrbin and Schlagenhauf, 1996).[2] In theory, sectoral productivity disturbances can play an important role in driving business cycles and transmitting them across borders.[3]

Against this backdrop, we analyze the common drivers of sectoral productivity fluctuations using cross-country data. Specifically, we address two interrelated questions: First, how important are global and sector-specific factors in explaining productivity fluctuations? Second, how important are these factors in accounting for sectoral business cycles?

Costello (1993), one of the studies that has a similar motivation to our paper, examined cross-country correlations of sectoral productivity for 5 sectors in 6 advanced economies. She also analyzes the impact of country-specific and sector-specific changes on productivity growth using an error-components model and. She finds strong evidence that productivity growth is more similar across sectors within a country but less similar across countries within a specific sector, suggesting that country-specific factors are more important drivers of sectoral productivity than sector-specific ones.[4] But the factors in her study were merely identified using fixed effects within each group, making it impossible to distinguish between common factors that are global in nature and those that are specific to sectors but common across countries.

Our study extends the earlier literature in several ways. First, we utilize a dynamic factor model to examine the common drivers of sectoral productivity fluctuations in 13 advanced economies over the past three decades.[5] Our model decomposes fluctuations of sectoral productivity into:

[1] These studies investigate the relative importance of sector-specific versus aggregate disturbances in explaining national cycles for the United States.

[2] They report that country-specific factors are more important than sector-specific ones. Karadimitropoulou and Leon-Ledesma (2013) also report that national factors have been the main drivers of sectoral business cycle fluctuations in the G7 economies during the 1974-2004 period.

[3] Following the seminal work of Kydland and Prescott (1982), many studies have documented the importance of productivity disturbances in explaining business cycles (See Pearsman and Straub (2009) for quantitative estimates based on standard models in the business cycle literature). Other studies emphasize that sectoral disturbances can propagate through input-output linkages and lead to aggregate business cycle fluctuations (Long and Plosser, 1983 and 1987; Plosser, 1989; Acemoglu et al., 2012).

[4] In a related paper, Vigfusson (2008) reports considerable cross-country comovement for US-Canada manufacturing sectors during 1961-97. He shows that higher correlations across sectors in the two countries can be explained by similarities in input usage.

[5] We follow Kose et al. (2003, 2008) who employ dynamic factor models to analyze commonalities in international business cycles using aggregate data.

(i) a global factor, which captures fluctuations common to all countries and sectors; (ii) sector-specific factors, which capture fluctuations common across countries within each sector; (iii) country-specific factors, which capture fluctuations common across sectors within each country; and (iv) idiosyncratic factors, which are specific to each sector in each country.

Second, we use data for a larger number of sectors and countries for a much longer period. Our sample extends beyond manufacturing and covers 15 sectors and 13 advanced economies (Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Spain, United Kingdom, and the United States) for the period 1981-2015. We make use of various vintages of the World KLEMS database and country-specific sources to put together the data and adjust total factor productivity series for unobserved input utilization. Compared to earlier datasets used in the literature such as Stockman (1988) and Norrbin and Schlagenhauf (1996), our dataset is much richer and more comprehensive with respect to the number of countries, sectors, and the length of the sample period. In addition, while earlier works on sectoral productivity comovement were limited to manufacturing (Costello, 1993; Vigfusson, 2008), we have a more extensive set of sectors that are large and trade the most with other countries.

Third, we use a factor-augmented vector autoregression (FAVAR) model to study the importance of global and sectoral productivity disturbance in driving business cycles.[6] While research has emphasized the importance of productivity disturbances as a driver of international business cycles, little work has been conducted on the role of sectoral disturbances in explaining business cycles.[7] To the best of our knowledge, our study is the first one focusing on the role of global and sector-specific productivity factors in explaining sectoral business cycles.

We report two major results. First, the common factors (the global and sector-specific factors) play a significant role in explaining sectoral productivity fluctuations. In particular, the global and sector-specific factors together account for close to 21 percent of the variation in sectoral productivity, ranging from 13 percent in the United States to 25 percent in France. This result suggests the existence of a global productivity cycle. Moreover, the importance of the global factor has increased following the 2008-09 financial crisis. Second, the global and sector-specific productivity factors explain, on average, about 26 and 16 percent of the variance of sectoral output fluctuations, respectively. The quantitative importance of the global productivity factor in explaining sectoral business cycles has risen over time, whereas that of the sector-specific factor has not changed much.

[6] The FAVAR model follows the work of Bernanke et al. (2005) who employ the framework to study the effects of monetary policy (see Stock and Watson (2016) for a survey of the dynamic factor and FAVAR models).

[7] See Backus et al. (1992) and Crucini et al. (2011), among others. Some recent papers identify exogenous shocks and provide evidence that they propagate across sectors (Acemoglu et al., 2016; Barrot and Sauvagnat, 2016; Huo et al. 2020).

Fourth, we utilize a dynamic general equilibrium model that considers sector-to-sector input output linkages both within and across countries to provide a theoretical explanation for our empirical findings. The model is an extension of multi-country, multi-sector international real business cycle (IRBC) model.[8] We extend the model by incorporating a productivity structure that captures the global, country-specific, and sector-specific common productivity factors following our empirical findings. We calibrate the model to the input-output linkages of 15 sectors and 13 countries (the same ones used in the FAVAR methodology described above). The model successfully replicates the empirical findings. Specifically, it matches the corresponding impulse responses and forecast error variance decompositions of sectoral output growth estimated from the FAVAR methodology.

In the model, each sector in each country produces a tradable differentiated good using capital, labor, and a composite intermediate good, which is an aggregate of intermediate goods produced by different source countries. Output is used both as an intermediate input in production of other sectors and countries and to produce a composite final good. Accordingly, the main international shock transmission mechanism operates through trade in both intermediate inputs and final goods.[9] More specifically, a common global, sector-specific, or country-specific shock can in fact be transmitted across sectors in different countries by input-output linkages not only through trade in final goods but also trade in intermediate inputs.

Our main motivation for considering this particular IRBC model is that: (i) it is capable of modeling multiple sectors in many countries, which is similar to the FAVAR model we used; (ii) it includes sector-to-sector input-output linkages both within and across countries, which allows to model the transmission of shocks to country- and sector-specific output growth rates through trade in final goods and intermediate inputs; (iii) it allows for varying input shares of intermediate goods across sectors, which is necessary to differentiate not only between goods- and services-producing sectors but also sectors within each category; and (iv) it allows to match several steady-state implications of the model to the World Input-Output Database, enabling us to calibrate the model in a way that aligns with actual data.

The rest of the paper is organized as follows. In Section 2, we detail the database and methodology. Section 3 provides a brief overview of the evolution of the estimated factors over time. In Section 4, we present the main findings regarding the drivers of sectoral productivity cycles. Section 5 examines the roles of global and sector-specific factors in explaining sectoral

[8] See for example Johnson (2014). In the corresponding literature, this IRBC model is an open economy analog to closed economy models of sectoral linkages as in studies pioneered by Long and Plosser (1983).

[9] Similar applications can be found in Huo, Levchenko and Pandalai-Nayar (2020) and Bonadio et al. (2020). In those papers the focus is on studying the role of production networks in international GDP comovement. In contrast, our work emphasizes the relevance of common productivity factors in explaining GDP comovement.

business cycles. Section 6 introduces the multi-country multi-sector dynamic general equilibrium IRBC model and compares its implications with those of the FAVAR methodology. Finally, in Section 7, we offer brief concluding remarks.

2. Database and Empirical Methodology

Our empirical exercise involves three major steps. First, we construct a dataset of sectoral productivity growth for 13 advanced economies. This dataset is constructed by combining sectoral output and factor input series from multiple sources and adjusting them for capacity utilization over the business cycle. Second, we use a dynamic factor model to estimate the common factors (global, sector- and country-specific) of productivity comovement across countries and sectors. We analyze the significance of each of these factors in explaining productivity fluctuations via variance decompositions. Finally, we explore the impact of global, sector- and country-specific productivity factors on sectoral business cycle fluctuations utilizing a FAVAR model.

2.1. Database

We collect data from various sources, including EU KLEMS, World KLEMS Growth and Productivity Accounts, and country-specific sources, to construct our dataset of sectoral productivity growth for 13 advanced economies.[10] Since the recent EU KLEMS updates provide data for capital and labor inputs only as far back as 1996, we use previous vintages of the data to extend the time coverage back to 1981. We calculate growth rates of each time series and extend the later vintage backward to reconstruct real values for each variable for the period 1981-2015.[11] We then compute total factor productivity series that are adjusted for capacity-utilization following Basu et al. (2006) (see Appendix A for the details of this adjustment).

Compared to earlier datasets used in the literature, our dataset is much richer and more comprehensive with respect to the number of countries, sectors, and the length of the sample period. First, we have data series for 13 advanced economies (Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Spain, United Kingdom, and the United States) for the period 1981-2015. Second, while previous work on sectoral productivity comovement is limited to manufacturing (Costello, 1993; Vigfusson, 2008), we have a much wider set of sectors that are large and most open to trade with other countries in our sample. For example, within manufacturing, our database includes all sectors that, on average, either account

[10] The acronym KLEMS stands for capital, labor, energy, materials, and business services. Data on output and inputs are available at the sectoral level for a number of countries and updated every few years. The data collection process is harmonized to insure comparability across sources. O'Mahoney and Timmer (2009) provide a detailed description of the dataset. For Canada, we use data from Statistics Canada.
[11] Specifically, the data is constructed combining the November 2019 and October 2012 Release of the data.

for more than one percent of the economy's total output during the 2000-15 period, or import inputs valued at least one percent of sectoral output from the other countries in the sample. Our dataset also includes the other goods-producing sectors (agriculture, mining and construction), and the market services sectors that import inputs valued at least 0.1 percent of sectoral output from the other countries in the sample. In total, our dataset includes 15 sectors.[12]

On average, sectoral productivity growth declined in all countries during the second half of our sample, and the decline appears to be broad-based across sectors. Bilateral correlation coefficients of productivity growth are, on average, positive but low (the mean correlation amongst all the sector-country series for the period 1981-2015 is 0.13), whereas those of output growth tend to be higher (0.29).[13] Average cross-country productivity (output) correlations for each sector range from 0.04 (0.02) in mining (mining), to 0.29 (0.56) in machinery (machinery) during the same period, respectively. Cross-country correlations of productivity growth have increased over time for twelve out of fifteen sectors. Cross-country output correlations have also increased substantially during the second half of the sample (in fourteen out of fifteen sectors). Cross-country correlations of both productivity and output growth appear to have been the highest for machinery (0.38 for productivity growth and 0.71 for output growth), plastics (0.30 for productivity growth and 0.60 for output growth), electrical equipment (0.30 for productivity growth and 0.54 for output growth), and transportation (0.30 for productivity growth and 0.47 for output growth) sectors during the second half of the sample period. These high cross-country correlations are suggestive of comovement that may be driven by common factors or cross-border spillovers (Tables B1 and B2).

2.2. Dynamic Factor Model

The model follows the dynamic factor framework in Kose et al. (2003) but extends it to a multi-sector environment.[14] Specifically, our dynamic factor model decomposes the growth rate of sectoral productivity into (i) a global factor, which captures fluctuations common to all countries and sectors; (ii) sector-specific factors, which capture fluctuations common across countries for each sector; (iii) country-specific factors, which capture fluctuations common across sectors within each country, and (iv) idiosyncratic factors, which are specific to each sector in each country.

[12] These sectors are food, textiles, publishing, chemicals, plastics, metal, machinery, electrical equipment, transport equipment, wholesale, transportation, communications, agriculture, mining, and construction (see Appendix A for details).

[13] These numbers are consistent with previous literature. For example, Ambler, Cardia and Zimmermann (2004) find that productivity correlations in aggregate data range between 0.16-0.25 during the 1960-2000 period.

[14] See Kose et al. (2003, 2008), Crucini et al. (2011), and Kose et al. (2012) for further details and applications of the dynamic factor model to cross-country settings.

Consider sectoral productivity growth, $z_{c,s,t}$, in country c $(c = 1, \dots, C)$, in sector s $(s = 1, \dots, S)$, at time t $(t = 1, \dots, T)$. Productivity growth has the following dynamic factor structure:

$$z_{c,s,t} = \sum_i \beta_{c,s}^i f_{i,t} + \varepsilon_{c,s,t}\ , \quad for \quad i \in \{G, S, C\} \tag{1}$$

where, $f_{i,t}$, for $i \in \{G, S, C\}$ denotes the latent global, sector-specific, and country-specific factors, respectively. The coefficients $\beta_{c,s}^i$, for $i \in \{G, S, C\}$ are called factor loadings and capture the sensitivity of each observable variable (on the left hand-side) to the global, sector-specific, and country-specific factors, respectively. The global, sector-specific, and country-specific factors are identified by imposing zero restrictions on factor loadings. That is, productivity in all countries and sectors load on to the global factor, but productivity in a specific sector loads onto that specific sector only across countries. The lag polynomials can in principle be of different order; however, for simplicity and parsimony, we follow Kose et al. (2003) and restrict them to follow and $AR(3)$ process for each factor and the idiosyncratic term $\varepsilon_{c,s,t}$:

$$f_{i,t} = \sum_{l=1}^3 \varphi_{i,l} f_{i,t-l} + v_{i,t}, \quad for \quad i \in \{G, S, C\} \tag{2}$$

where, $v_{i,t} \sim N(0, \sigma_i^2)$. $\varepsilon_{c,s,t}$ denotes the error term in (1), which is assumed to be uncorrelated cross-sectionally at all leads and lags but can be serially correlated. The error term follows an autoregressive process of order 3:

$$\varepsilon_{c,s,t} = \sum_{l=1}^3 \delta_{c,s,l} \varepsilon_{c,s,t-l} + e_{c,s,t} \tag{3}$$

where $e_{c,s,t}$ are distributed as $N(0, \sigma_{c,s}^2)$. The innovations, $\varepsilon_{c,s,t}$, and $v_{i,t}$, for $i \in \{G, S, C\}$ are mutually orthogonal across all equations in the system. For comparison purposes, we also estimate the model using sectoral output growth for the same sample of countries and years.

Estimation. There are two related identification problems in the model (1) - (3). The signs and the scales of the factors and their loadings are not separately identified. To overcome the sign identification issue, the factor loadings of one series are restricted to be positive for each of the factors. In particular, the factor loading for the global factor is required to be positive for the growth rates of the first sector of the first country in the dataset; each sector-specific factor is restricted to load positively onto the sectoral series of the first country in the dataset; and, finally, the factor loadings for the country factors have to be positive for the first sectoral series of each country.[15] Scales can be identified by assuming that σ_i^2, for $i \in \{G, S, C\}$ is constant.

[15] In our baseline specification, the United States is the first country in the dataset and food (Food Products, Beverages and Tobacco) is the first sector. The results are similar using other sectoral series of each country for the identification of the signs and are available upon request.

The model is estimated using Bayesian methods by using Gibbs Sampling techniques. "Gibbs sampling" is the sequential sampling of the full set of conditional distributions, generated using a Markov Chain Monte Carlo (MCMC) procedure. This is feasible in this case as the full set of conditional distributions is known. That is, parameters given data and factors, and factors given data and parameters. Conditional on a draw for factors as given, the procedure first estimates the AR coefficients and the variance of the shocks in equations (2) – (3). Next, conditional on a draw of factors, the procedure generates the factor loading $\beta^i_{c,s}$, for $i \in \{G, S, C\}$. Then, the procedure simulates $f_{i,t}$, for $i \in \{G, S, C\}$ conditional on all parameters above. This constitutes one step of the Markov-Chain. This process is then repeated 20,000 times generating at each step drawings for the regression parameters and the factors.

Previous studies on productivity comovement use panel regression methods (error-components model) to capture common dynamics in productivity (Costello 1993). Compared to this approach, our dynamic factor model has two main advantages. First, it is a parametric model that allows us to decompose productivity movements into well-defined orthogonal (global, sector-specific and country-specific) factors. Second, our model captures dynamic lead-lag correlations as opposed to just contemporaneous correlations.

As discussed, the idiosyncratic term and factors follow an AR (3) process. The prior on all the factor loadings is $N(0,1)$, while the one for the autoregressive polynomial parameters is $N(0, \Sigma)$, where $\Sigma = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0.5 & 0 \\ 0 & 0 & 0.25 \end{bmatrix}$. The results are robust to using tighter or looser priors for both the factors and autoregressive parameters. The prior on the innovation variances in the observable equations is Inverted Gamma $(6, 0.001)$, which is quite diffuse.

Variance decompositions. To gauge the importance of the global, sector-specific and country-specific factors in explaining fluctuations in productivity growth, we estimate the share of the variance of productivity growth due to each factor. The variance of $z_{c,s,t}$ with orthogonal factors is given by:

$$var(z_{c,s,t}) = \sum_i (\beta^i_{c,s})^2 var(f_{i,t}) + var(\varepsilon_{c,s,t}), for\ i \in \{G, S, C\} \tag{4}$$

The fraction of fluctuations due to factor $f_{i,t}$, for $i \in \{G, S, C\}$ is computed as:

$$\frac{(\beta^i_{c,s})^2 var(f_{i,t})}{var(z_{c,s,t})} \tag{5}$$

Equations (4) and (5) are computed at each step of the Markov-Chain. Since the factors are orthogonal by construction, there are no covariance terms when we apply the variance operator.[16]

2.3. FAVAR Model

We use a Factor-Augmented Vector Autoregressive (FAVAR) model to evaluate the roles of common productivity factors in explaining sectoral business cycles. A FAVAR is simply a vector autoregressive (VAR) model that includes one or more latent factors in addition to observables. Identification of the structural shocks within the FAVAR can be achieved by conventional methods. We follow the two-step method by Bernanke et al. (2005): we first estimate the common factors. We then use the estimated factors in an otherwise standard VAR along with sectoral output.

The FAVAR model can be represented by:

$$y_t = a_{(0)} + A_{(1)} y_{(t-1)} + u_t \, ; t = 1, \dots, T \tag{6}$$

where y_t is an $m \times 1$ vector of variables at date t, A_i is an $m \times m$ coefficient matrix for each lag of the variable vector with $a_{(0)}$ being the constant term, and m is the number of variables in the model. The vector of error terms is denoted by u_t. The variables we include in the VAR are the global, sector-specific, and country-specific factors estimated in the previous section and sectoral output (value added) growth. In our estimation, the lag length is kept at three, similar to the dynamic factor model.[17]

Identification. We identify shocks using a recursive identification. The ordering of the variables is based on the presumed exogeneity, or predetermination, of variables where more exogenous variables are ordered first. For example, it assumes that the global factor is relatively more exogenous compared to the sector-specific factor given that the latter is specific to one sector across countries, whereas the former is common to all sectors in all countries. This implies that the ordering of the variables in the model is the following: the global productivity factor, sector-specific productivity factor, country-specific productivity factor, and sectoral output growth.

Estimation. Since we have a FAVAR model for each sector, we estimate 195 different models (for 15 sectors in 13 countries). To illustrate, to examine the drivers of fluctuations in machinery

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[16] Even though the factors are uncorrelated, samples taken at each step of the Markov-Chain may not be, purely because of sampling errors. To account for possible correlation in finite samples, the estimated factors are further orthogonalized, ordering the global factor first, the sector-specific factor second, and the country-specific factor third.

[17] Results are similar when the lag length is equal to one. Given the fact that number of observations is limited, this lag length constitutes a reasonable benchmark (see Hirata et al. (2013) for a more detailed discussion).

sector in the United States, we estimate a FAVAR model that includes the global factor, the machinery sector-specific factor, the United States country-specific factor, and United States machinery sector's output. We report variance decompositions as well as impulse responses to gauge the impact of fluctuations in each factor on sectoral output growth.

3. Evolution of Global and Sector-Specific Productivity Factors

Global Factor. Figure 1 (top panel) plots the global productivity factor (solid red line) and the 33 and 66 percent quintile bands (dashed lines). The tightness of the bands shows that the factor is estimated quite precisely. We compare the global productivity factor with the global output factor (in the bottom panel) that is based on a dynamic factor model estimated for the same sample of countries, sectors and period.[18] The shaded areas denote the periods of global recessions or slowdowns.[19]

The global productivity factor captures several of the peaks and troughs associated with the global recessions and slowdowns. For example, it declines during the global recessions or slowdowns (1982, 1991, and 2001) and more recently during the latest global recession (associated with the global financial crisis of 2008-09). These recession episodes coincide with highly synchronized downturns in sectoral productivity. In the years before the global financial crisis, the growth rate of the global factor peaked around 2004, before it started to decline. This date corresponds to the beginning of the recent productivity slowdown in advanced economies (Cette et al., 2016; Fernald et al., 2023). After a rapid rebound following the global financial crisis, the decline in productivity growth continued. As one would expect, movements in the global productivity factor are in line with those in the global output factor.

Country factors. Figure 2 presents the country-specific productivity factors for the United States, Japan, and Germany, the three countries with the highest GDP in our sample. These factors are able to capture the major country-specific recession episodes. For example, in Japan, the country-specific factor declined in the beginning of the 1990s recession, after the stock price crash, and during the domestic financial crisis in the late 1990s and early 2000s. Similarly, the country-

[18] The model is similar to the one in equations (1) - (3), and includes the global, sector-specific and country-specific factors. The only difference is that it is estimated using data on sectoral output (value added) growth. To compare the results with those of our baseline estimates, we further compute variance decompositions of sectoral output growth as in (4) and (5) above.

[19] Although these global recessions were triggered by different types of shocks, each of them was accompanied by multiple financial crises in different parts of the world: recessions following monetary policy tightening in major advanced economies and debt crises in many EMDEs (1982); credit crunch in the United States, and banking and currency crises in many European countries (1991); and financial crises in major advanced economies (2008-09). The global economy also experienced two significant growth slowdowns during the 1997-98 Asian Crisis and the 2001 dotcom bust that coincided with recessions in major advanced economies and financial crises in some EMDEs. For details about the history of global recessions, see Kose and Terrones (2015).

specific factor for Germany plummeted in the 1991 recession that coincided with the reunification.

Sectoral factors. Figure 3 shows the evolution of four sector-specific factors, including machinery, transportation, communications, and agriculture.[20] Movements in these sector-specific factors closely aligned with global business cycles. For example, they seem to decline during global recessions and slowdowns. They started falling in mid-2000, exacerbating the downturn in the growth rate of the global productivity factor. The communication-specific factor fell sharply after the early-2000 reflecting the slowdown in ICT and ICT-related sectors across countries following the dot.com bust.[21]

Since the sector-specific factors are orthogonal to the global factor in our framework, a sector-specific factor picks up cross-country common sectoral movements after purging those already accounted by the global factor. The decline in most of the sector-specific factors during the global financial crisis suggests that sector-specific developments have an additional role in explaining the dip in productivity during this episode. Having said that, compared to the sharp decline in the global factor, the drop-in sector-specific factors is less pronounced during the global financial crisis. This implies that, after accounting for the global factor, the role of the sector-specific factors in explaining the decline in productivity growth during the latest financial crisis is relatively smaller.

Factors and Observables. To better understand the roles played by different factors in different time periods, we study the evolutions of the estimated factors along with sectoral productivity and output series. In Figure 4, we plot the global, sector- and country-specific productivity factors along with the productivity series for the Machinery sector in the United States, Japan, and Germany. To make the scales comparable, the world, sector-, and country-specific factors are multiplied by their factor loadings.

Three main observations emerge from these figures. First, the global productivity factor captures the major turning points of the global business cycle. During the last global recession, the global

[20] Sector selection is based on the unique characteristics of these sectors and their relative importance in an economy. Machinery is one of the main sectors in manufacturing. It is one of the sectors with the most liquid assets, highest net worth, and highly correlated output growth with rest of the economy (Everts, 2006; Oviedo and Sing, 2013). Transportation is found to be one of the most correlated sectors with the rest of the economy in the United States (Everts, 2006). Communications sector includes information and communications technologies (ICT), which has been mentioned as leading the productivity slowdown in the United States (Fernald, 2015; Syverson, 2017). Agriculture, on the other hand, is one of the least correlated sectors with the rest of the economy (Everts, 2006; Da-Rocha and Restuccia, 2006).

[21] This observation supplements Fernald (2015) who argues that the beginning of the recent slowdown in productivity in the United States can be traced back to the end of an exceptional growth period in ICT and ICT-related sectors.

factor played a major role in pulling down productivity growth in the Machinery sector as the episode witnessed an unprecedented degree of cyclical comovement. Second, both the sector- and country-specific productivity factors appear to have played roles in explaining fluctuations in productivity growth at different time periods. For example, the U.S. country-specific factor appears to have started to contribute negatively to productivity growth since the mid-2000. For Germany, the global factor is a major driver during the 2001 recession (which corresponded to a global slowdown). However, during the 1991 recession, the German country-specific factor is the main driving force of productivity movements as the unification and exchange rate crisis took a heavy toll on the economy. For Japan, the country-specific factor accounts for the recession in the late 1990s, which corresponds to the balance sheet recession including the recession due to the non-performing loans problem of the Japanese financial institutions. The negative shocks arising from Great East Japan Earthquake in 2011 are captured by the country-specific factor.

These observations broadly hold across sectors. The sector-specific factors play a more important role in some sectors than do others. For example, in the case of machinery, the global factor appears to be the main driver of productivity growth in the late 2000s, even though the sector- and country-specific factors played a substantial role in the earlier periods. In agriculture, it appears that the sector-specific and country-specific factors play a dominant role even during the latest financial crisis of 2008-09.

4. Drivers of Productivity Cycles

4.1. Baseline Results

We analyze the importance of each factor in explaining productivity cycles in this section. Figure 5 (and Tables 1-2) present the average share of variance due to each factor for each country and sector in our sample. Two major results emerge about the common drivers of productivity fluctuations. First, the global factor accounts for a sizeable share of the variation in productivity. It explains, on average, about 10 percent of the variance in productivity growth, ranging from 4 percent in the United States to 17 percent in the United Kingdom. Given that the average share is based on a sample of 195 sectors (15 sectors and 13 countries), the role of the global factor is quite significant implying the presence of a global productivity cycle (more detailed estimates can be found in Tables B3 and B4). Second, the sector-specific factors are also important in driving sectoral productivity fluctuations. They explain on average about 11 percent of the variance of productivity growth. The share due to the sector-specific factor ranges from 8 percent in Canada to 21 percent in France. Our first two findings suggest that the two common (the global and sector-specific) factors together account, on average, for about one-fifth of the sectoral productivity variance.

We compare the common drivers of productivity cycles with those of business cycles (Figure 5 and 6 and Tables 1-2). The results suggest that the global factor explains a larger share of business cycle fluctuations than productivity cycles. This evidence suggests that a larger role of the global factor in explaining business cycles, compared to that of productivity fluctuations, may be driven by factors not related to productivity growth, such as spillovers through channels pertaining to market frictions or demand factors. Some other potential mechanisms that generate demand spillovers proposed in the literature include credit market frictions (Kiyotaki and Moore, 1997), macroprudential interventions (Fahri and Werning, 2016), fiscal spending and other demand shocks, such as an unanticipated increase in imports (Acemoglu et al., 2016).

The presence of international productivity cycles is examined by a small number of papers in the literature. Imbs (1999) and Ambler, Cardia, and Zimmermann (2004) find that cross-country productivity correlations are driven by correlations in inputs in production.[22] Other studies identify both technology and demand shocks in a VAR setting as drivers of international propagation of business cycles (Canova, 2005; Corsetti, Dedola, and Leduc, 2014). Relatedly, a different strand of literature finds that trade, both at the intensive and extensive margins, is correlated with higher output and productivity comovement (Frankel and Rose, 1998; Liao and Santacreu, 2015).[23]

In addition, the sector-specific factor accounts for a larger share of the variation in productivity than the global factor whereas the global factor is more important than the sector-specific factor in explaining the variance of output growth. In our setup, the sectoral factors could capture sector-specific demand shocks, cost shocks, or sectoral shocks that are transmitted across borders via cross-border sectoral linkages (Acemoglu et al., 2016; Di Giovanni et al., 2014). For both productivity cycles and sectoral business cycles the global and sector-specific factors on average account for a larger share of the variation in respective cycles than that due to the country-specific factor. Specifically, the two common factors together explain about 21 (34) percent of productivity (business) cycles while the country-specific factor accounts for 13 (17) percent. This would suggest that the drivers of sectoral business cycles are likely global in nature, and not primarily specific to countries.

How do these results compare with previous findings? Costello (1993) finds that the country-specific factor explains 25-33 percent of productivity fluctuations, depending on the specification. Our findings suggest a smaller role for country-specific factors. Unfortunately, due to data

[22] Lazear (2019) suggests that skill-biased technological change has made productivity growth more correlated in industries dominated by highly educated workers across European countries.

[23] Some papers study models in which fluctuations are driven by productivity shocks and find that increased trade and correlated productivity fluctuations can generate international business cycle comovement closer to what is observed in the data (Kose and Yi, 2006; Johnson, 2014).

limitations, a direct comparison of our findings with Costello (1993) is not possible. However, the differences can be explained by several reasons. First, as explained above, the methodology in her study does not disentangle between global and sector-specific factors. As a result, the country-specific factor in Costello's study could be capturing common movements that are global in nature.[24] Second, the sample ends in 1984 in her study, which does not include the era of globalization that may have enhanced the role of the global factor. Third, Costello (1993) uses residuals that are not adjusted for capacity utilization as a measure of TFP, which may lead to spurious correlation among the series.

Stockman (1988) finds that each of the sector- and country-specific factor explain 22-30 percent of output fluctuations, depending on the specification. His dataset includes 7 countries and 10 manufacturing sectors for the 1964-1984 period. The methodology used in Stockman (1988) is similar to the one in Costello (1993), and therefore, a direct comparison with our results is not possible. Norrbin and Schlagenhauf (1996) use a dynamic factor analysis state-space approach to decompose fluctuations in sectoral output into country-specific, sector-specific, common and idiosyncratic factors. Their dataset includes quarterly and semi-annual data for 11 countries and 7 sectors during the period 1956:1-1992:4. They find that the country-specific factor explains close to 30 percent of fluctuations, ranging from 4 percent in the Netherlands to 58 percent in France. By contrast, the sector-specific and common factors in their specification explain only 11 and 14 percent of fluctuations, respectively, and are similar to our reported estimates.

Our results are also consistent with those reported in Karadimitropoulou and Leon-Ledesma (2013) and Karadimitropoulou (2018) who employ a similar methodology to analyze sectoral output comovement in G7 economies. Using value added data for 30 sectors they find that the global factor explains about 10 percent of sectoral fluctuations in the G7 countries during the 1974-2004 period, whereas sector and country-specific factors explain 12 and 17 percent of fluctuations, respectively.[25]

4.2. Drivers of Productivity Over Time

We next examine how the importance of global and sector-specific factors has changed over time. This is especially important since our sample covers the 2008-09 global recession, a period of

[24] Allowing only for sector- and country-specific factors in our specification, we find that the country-specific factors explain a larger share of productivity fluctuations than before. The country-specific factors explain on average 21 percent of productivity fluctuations, ranging from 14 percent in Finland to 27 percent in Germany and Italy. This is larger than the share of fluctuations explained by the sector-specific factors (13 percent), which range from 8 percent in the United States to 20 percent in France.

[25] Our estimates for the variance decompositions of the global, sector-specific, and country-specific factors of sectoral output growth are similar to Karadimitropoulou and Leon-Ledesma (2013) when excluding the 2007-09 global financial crisis period.

highly synchronized cycles. To better understand the evolution of the importance of the common factors, the model is estimated over two sub-periods: 1981-1997 and 1998-2015. We also check the robustness of the sub-sample results by estimating the model over rolling samples.

Figures 7 and 8 present the variance shares explained by the global and sector-specific factors over time. The figures point to four major results. First, the global factor explains a larger share of the variance in the latter period: the average share of variance due to the global factor increases from 8 percent in 1981-1997 to 19 percent in 1998-2015. The global factor accounts for a larger share of productivity cycles in all countries and in all sectors except four in the latter period.

Second, the increase in the share of variance due to the global factor is mainly because of the global recession as the importance of the global factor registers a significant jump when the post-2008 period is included in the sample.[26] Third, contrary to the role of the global factor, the role of the sector-specific factors has not changed much over time in explaining productivity growth. These results are consistent with the large common (global) disturbances and coordinated policies during the second sub-period. The increased relevance of these commonalities, though, appears to have been global (common to all sectors in all countries), and not necessarily sector specific.[27]

4.3. Robustness

To check the sensitivity of our results, we conduct a battery of robustness exercises. We employ different country samples, different time periods, alternative productivity series and analyze the roles of specific countries. Figures 9-11 summarize our findings.

Sample selection. We check how our results change when we have the sub-samples of G7 countries and 9 members of the European Union plus the United Kingdom. The results are broadly in line with our baseline findings. As one would expect, because of the harmonization among the European union member countries, the role of the global factor appears to be larger for that sample.

Data treatment. We check the robustness of our results when productivity series are not adjusted for capacity-utilization. As discussed in Section 2, the unadjusted data could spuriously lead to higher comovement. The results appear to suggest a slightly stronger role for the global

[26] The post-2008 period corresponds to sluggish investment growth and increased uncertainty, factors that may have contributed to the slowdown in productivity growth in advanced economies (Bloom, 2009).

[27] While increased vertical specialization could increase technological spillovers and lead to a higher productivity comovement over time, increased trade and financial integration can also increase specialization, resulting in less synchronized cycles across countries (Obstfeld, 1994).

and sector-specific factors. We also estimate the model by changing the lag length of the autoregressive process for the factors (from AR(3) to AR(1)). In addition, instead of total factor productivity, we estimate the same model using labor productivity. Again, the results are similar to our headline findings.

We also check whether our robustness exercises lead to similar findings over time. Our headline finding is that the global factor has been becoming more important over time whereas the role of the sector-specific factor has not changed much. These headline findings are robust to using different samples and alternative productivity series.

Roles of specific countries and sectors. We also check whether any particular country is driving the results. Figure 11 shows the variance shares due to the global and sector-specific factors while dropping one country at a time. The results are again in line with our baseline findings. The results are similar when including a broader set of sectors and when dropping the agriculture sector, which may be subject to weather shocks and availability of land and water.

5. Drivers of Sectoral Business Cycles

Baseline Results. We report the estimated variance of sectoral output fluctuations explained by the global, sector-specific and country-specific factors for each country and sector based on the FAVAR model (Table 3). Three major results emerge. First, both the global and sector-specific factors are important drivers of sectoral business cycles. The global factor on average accounts for 24 percent of output fluctuations (over the one-year horizon), ranging from 15 percent for the Austria to 35 percent for Italy. The sector-specific factor explains 11 percent of cycles (over the one-year horizon), ranging from 7 percent for Italy to 21 percent for France. This finding is consistent with previous studies using aggregate data (e.g., Crucini et al., 2011).[28]

Second, the importance of the common factors in explaining sectoral business cycles varies across sectors. For example, the share of variance due to the global factor ranges from less than 10 percent in agriculture to more than 30 percent in some other sectors (e.g., plastics, metals, machinery, transport equipment, and transportation). That of the sector-specific factor ranges from less than 10 percent (e.g., metals and transportation) to around 15 percent or higher (e.g., machinery and agriculture). The global factor appears to have a sizeable role in explaining sectoral fluctuations in metals, machinery, electrical equipment, transport equipment, and transportation sectors. These sectors tend to have the highest correlations with the rest of the economy and are usually closely connected with other sectors through real (via trade of

[28] Crucini et al. 2011 find that common productivity factors explain on average 33 percent of output fluctuations in G7 countries for the period 1960-2005. Peersman and Straub (2009) and Dedola and Neri (2007) find that technology shocks account for 20-30 percent of output fluctuations in the Euro area and the United States.

intermediate goods) and financial linkages (see Oviedo and Sing 2013; Everts 2016; Foerster et al., 2019; Lehn and Winberry, 2022).

However, the role of the global factor in explaining fluctuations in agriculture (the sector least correlated with other sectors) is much smaller. The sector-specific and country-specific factors play a dominant role in driving agricultural fluctuations.[29] We also analyze the roles of the global and sector-specific factors in explaining sectoral cycles in three largest economies (the United States, Japan, and Germany) in our sample (Table 4). The results again suggest that the global factor tends to play a more influential role in more open economies and sectors (for example, the machinery sector in Germany) but a much smaller role in other sectors (such as agriculture).

Third, the importance of the common factors in explaining sectoral business cycles varies over time (Table 5). We divide the sample into two subperiods (1981-1997 and 1998-2015) to study the temporal variation. The results indicate that while the global productivity factor is more important in the latter period, the variance shares due to the sector- and country-specific productivity factors do not change much. The share of sectoral output variance explained by the global productivity growth factor, on average, increases by 29 percentage points, from 10 percent to 39 percent) over the sub-periods while that of the sector- specific factor declines slightly, from 16 percent to 12 percent. When we experiment with alternative sub-samples that do not include the recent global financial crisis, the change in the importance of global factor is much smaller, suggesting that the results are due to the dominance of the common shock associated with the latest global recession.

Figures 12-15 show the impulse responses of sectoral output growth in response to a global, sector-specific, and country-specific productivity factor variations estimated from the FAVAR model (solid black lines).[30] Specifically, Figure 12 shows the response of the global productivity factor fluctuation on sectoral output growth for each sector (as averages across 13 countries), whereas Figure 13 shows the response of sectoral output growth to common global productivity factor variation for each country (as averaged across 15 sectors). Similarly, Figure 14 shows the effects of a common sector-specific factor variation on sectoral output growth for each sector (as averaged across 13 countries). Finally, Figure 15 shows the effects of a country-specific factor change on sectoral output growth for each country (as averaged across 15 sectors).

These impulse responses suggest positive effects of the global, sector-specific and country-specific productivity factor fluctuations on sectoral output growth, although the significance of these effects based on the 16-84% percentile bands is mixed across sectors or countries.

[29] These findings are consistent with Everts (2006) and Da-Rocha and Restuccia (2006) who emphasize the distinct features of agricultural sector business cycles in a cross-country study.
[30] We estimate impulse responses of 195 sectoral output growth rates (representing 15 sectors in 13 countries). The figures show medians across sectors and countries

Regarding their pattern over time, all impulse responses are pronounced on impact but die out rather quickly. This result is consistent with earlier studies that also find that the effect of a sectoral shock on the growth rate of output subsides relatively quickly (Long and Plosser, 1983; Acemoglu et al. 2016). These findings are also consistent with the predictions of RBC models (Peersman and Straub, 2009).

Sensitivity Analysis. We analyze the robustness of our headline findings by conducting a variety of sensitivity exercises. First, we use alternative productivity measures, including labor productivity and a total productivity measure that is not adjusted for capacity utilization. Second, we estimate the model by excluding certain countries from the sample. Third, we experiment with different ordering of factors in the model. These sensitivity experiments do not lead to any significant changes from the headline findings.

6. Global, sector-specific, and country-specific productivity factors in general equilibrium

We test whether the empirical findings of the FAVAR model are consistent with the implications of a dynamic general equilibrium international real business cycle (IRBC)model with multiple sectors and many countries. Our model is based on Johnson (2014). But, to ensure consistency with the FAVAR model, we consider a version of this IRBC model with 15 sectors and 13 countries (the same ones used in the FAVAR estimates presented in the previous section). We also extend the model by considering an alternative productivity process that comprises global, sector-specific, and country-specific productivity factors (similar to the one used in the FAVAR methodology estimates). The model is introduced below, whereas its additional details and solution are provided in the Appendix.

This particular extension of the IRBC model is a suitable framework for testing our empirical findings for several reasons. First, the model is capable of capturing a dynamic world economy model with multiple sectors and countries, which is consistent with our empirical setting. Second, the extended IRBC model features productivity processes that account for global, sector-specific, and country-specific common factors, as motivated by our empirical results. Third, unlike the standard IRBC model, it incorporates sector-to-sector input-output linkages both within and across countries, which is essential for analyzing the channels through which shocks propagate (Country- and sector-specific output shocks transmit through trade in both final goods and intermediate inputs). Fourth, the model incorporates varying input shares of intermediate goods across sectors, allowing to distinguish between sectors within both goods- and services-producing categories. Finally, several steady-state implications of this IRBC model can be matched with moments derived from the World Input-Output Database, enabling us to calibrate the model in a manner that aligns with actual data.

6.1. IRBC Model

The multi-period world economy has many countries ($i, j \in \{1, \dots, N\}$) and multiple sectors ($s, s' \in \{1, \dots, S\}$). The main idea of this model is to consider sector-to-sector input-output linkages both within and across countries. Specifically, each country produces a tradable differentiated good in each sector using capital, labor, and a composite intermediate good, which is an aggregate of intermediate goods produced by different source countries. Output is used both as an intermediate input in production of other sectors and countries and to produce a composite final good. Accordingly, the main international shock transmission mechanism operates through trade in final goods and intermediate inputs. The formal details of the model are provided next.

Production. At any time t, each country i produces a tradable differentiated good $Q_{it}(s)$ in sector s using labor $L_{it}(s)$, capital $K_{it}(s)$, and a composite intermediate good $X_{it}(s)$. Formally, the sector-level production function for $Q_{it}(s)$ is given by:

$$Q_{it}(s) = Z_{it}(s)\left(\theta_i(s)^{1-\sigma}V_{it}(s)^{\sigma} + \left(1-\theta_i(s)\right)^{1-\sigma}X_{it}(s)^{\sigma}\right)^{1/\sigma} \tag{7}$$

where the composite intermediate good is given by:

$$X_{it}(s) = \sum_{j=1}^{N}\sum_{s'=1}^{S}\left(\omega_{ji}^{x}(s',s)^{1-\eta}X_{jit}(s',s)^{\eta}\right)^{1/\eta} \tag{8}$$

and $V_{it}(s)$ represents a domestic input factor as follows:

$$V_{it}(s) = K_{it}(s)^{\alpha}L_{it}(s)^{1-\alpha} \tag{9}$$

In these equations, $Z_{it}(s)$ represents the sector-level productivity (to be further connected to the productivity factors of the FAVAR methodology, below), $X_{jit}(s',s)$ is the quantity of intermediate goods from sector s' in country j used by sector s in country i, $\left\{\theta_i(s), \omega_{ji}^{x}(s',s), \alpha\right\}$ represent parameters that govern input shares, and $\{\sigma, \eta\}$ are elasticity measures. Under perfect competition, the profit maximization problem is given by:

$$\max \;\; p_{it}(s)Q_{it}(s) - w_{it}L_{it}(s) - r_{it}K_{it}(s) - \sum_{j=1}^{N}\sum_{s'=1}^{S}p_{jt}(s')X_{jit}(s',s) \tag{10}$$

subject to $L_{it}(s) \geq 0, K_{it}(s) \geq 0, X_{jit}(s',s)K_{it}(s) \geq 0$, where $p_{it}(s)$ is the output price, w_{it} is the wage, and r_{it} is the rental rate of capital.

A composite final good in each country i is produced by combining sector-level composites of all sectors according to:

$$F_{it} = \prod_{s=1}^{S} F_{it}(s)^{\gamma_i(s)} \tag{11}$$

where $F_{it}(s) = \left(\sum_j \omega_{ji}^f(s)^{1-\rho} F_{jit}(s)^{\rho}\right)^{1/\rho}$ represents a sector-level composite consisting of intermediate goods $F_{jit}(s)$'s purchased from different countries, with $\{\gamma_i(s), \omega_{ji}^f(s)\}$ governing input shares, and ρ is an elasticity measure.[31] The corresponding profit maximization if given by:

$$\max \; p_{ji}^f F_{it} - \sum_{j=1}^{N} \sum_{s=1}^{S} p_{jt}(s) F_{jit}(s) \tag{12}$$

subject to $F_{jit}(s) \geq 0$, where p_{ji}^f is the price of the composite final good.

Productivity process. The FAVAR methodology is connected to the IRBC model through the productivity process. As the FAVAR methodology considers global, sectoral and country-specific factors of productivity, in the IRBC model, we define the following equation for the log-linearized sector-level productivity:

$$\hat{Z}_{it}(s) = \beta_i^G(s)\hat{Z}_t + \beta_i^S(s)\hat{Z}_t(s) + \beta_i^C(s)\hat{Z}_{it} \tag{13}$$

where $\hat{Z}_t$, $\hat{Z}_t(s)$ and $\hat{Z}_{it}$ represent global, sector-specific and country-specific productivity factors, and $\beta_i^G(s)$, $\beta_i^S(s)$ and $\beta_i^C(s)$ represent the coefficients estimated according to Equation (1) by the dynamic factor model.

As the FAVAR methodology utilizes the growth rate of sectoral productivity, we define the growth rate of global productivity $\hat{z}_t$ as follows in the IRBC model:

$$\hat{z}_t = \hat{Z}_t - \hat{Z}_{t-1} \tag{14}$$

It is assumed in the IRBC model that $\hat{z}_t$ follows an AR(1) process according to:

$$\hat{z}_t = \varphi \hat{z}_{t-1} + v_t \tag{15}$$

where φ is the AR(1) coefficient for the global productivity factor, and v_t is the global shock. This can be rewritten by using $\hat{z}_t = \hat{Z}_t - \hat{Z}_{t-1}$ as follows:

$$\hat{Z}_t = (1+\varphi)\hat{Z}_{t-1} - \varphi \hat{Z}_{t-2} + v_t \tag{16}$$

which we use in the model calibration.

In a similar way, for the sector-specific productivity factor, we can write:

$$\hat{Z}_t(s) = \big(1+\varphi(s)\big)\hat{Z}_{t-1}(s) - \varphi(s)\hat{Z}_{t-2}(s) + v_t(s) \tag{17}$$

[31] ρ is defined as one minus the inverse of the elasticity of substitution across imported goods.

where $\varphi(s)$ is the sector-specific AR(1) coefficient, and $v_t(s)$ is a sector-specific shock.

Finally, for the country-specific productivity factor, we can write:

$$\hat{Z}_{it} = (1+\varphi_i)\hat{Z}_{it-1} - \varphi_i \hat{Z}_{it-2} + v_{it} \tag{18}$$

where φ_i is the country-specific AR(1) coefficient, and v_{it} is the country-i-specific shock.

Consumption. The consumer's utility function is given by:

$$U_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left[log(C_{it}) - \frac{\chi^\varepsilon}{1+\varepsilon} L_{it}^{\frac{1+\varepsilon}{\varepsilon}} \right] \tag{19}$$

where C_{it} is consumption, L_{it} is labor supply, ε is the Frisch elasticity of labor supply, and β is the rate of time preference. The budget constraint is given by:

$$p_{ji}^{f}(C_{it} + I_{it}) + \int B_i(\widetilde{\omega}_{t+1}) b(\widetilde{\omega}_{t+1}, \widetilde{\omega}_t) d(\widetilde{\omega}_{t+1}) = w_{it}L_{it} + r_{it}K_{it} + B_i(\widetilde{\omega}_t) \tag{20}$$

where I_{it} is investment, $B_i(\widetilde{\omega}_{t+1})$ is country i's holdings of a one-period state-contingent bonds and $b(\widetilde{\omega}_{t+1}, \widetilde{\omega}_t)$ is the corresponding price in state $\widetilde{\omega}_t$.

Equilibrium. The market clearing condition for the sector-level production is given by:

$$Q_{it}(s) = \sum_{j=1}^{N} \sum_{s'=1}^{S} F_{ijt}(s) + X_{ijt}(s, s') \tag{21}$$

where it is used either for the production of the composite final good or sector-level production. Capital evolves according to:

$$K_{it+1} = I_{it} + (1-\delta)K_{it} \tag{22}$$

where $K_{it} = \sum_{s=1}^{S} K_{it}(s)$. The labor market clearing condition is given by $L_{it} = \sum_{s=1}^{S} L_{it}(s)$. Finally, the composite final good is used either for consumption or investment according to $F_{it} = C_{it} + I_{it}$.

6.2. IRBC model calibration

In order to align with the FAVAR methodology, we calibrated the IRBC model for the 15 sectors and 13 countries (same as the ones used in the FAVAR methodology). Appendix C contains the technical specifics of the calibration process, while we present a comparison of impulse response functions and forecast error variance decompositions between FAVAR and IRBC models in this section.

Figures 12-15 present the impulse responses obtained through the IRBC model, which can be compared to those obtained through the FAVAR methodology. The figures show that the IRBC model effectively reproduces the impulse responses of sectoral output growth rates in response to shocks in a common global, sector-specific and country-specific productivity factors. Specifically, the impulse responses generated by the IRBC model consistently fall within the 16-84 percentile bands of the FAVAR model estimates and closely track the median estimate in the majority of cases.

Figure 12 illustrates the impact of a common global productivity shock on sectoral output growth (for each sector) across 13 countries, while Figure 13 illustrates the impact for each country across 15 sectors. The success of the IRBC model in matching the impulse responses of the FAVAR model in these figures is based on matching the effects of only a single shock (of a common global productivity factor). Although the IRBC model can successfully replicate the impulse responses of the FAVAR model when the corresponding 16-84 percentile bands are used, the replication for some sectors and countries are better than others when the median impulse responses are considered, especially for the initial response. Specifically, initial impulse responses of sectors such as textile, publishing, chemicals, wholesale, transportation, and those of countries such as Austria, Denmark, Germany, Netherlands are replicated relatively better than those of other sectors and countries. Regarding the economic intuition behind these results, the consistency between the FAVAR methodology and the IRBC model calibration suggests that *a common global productivity shock* can affect sectoral output growth not only through aggregate demand but also through the intermediate inputs purchased from all sectors in all countries.

Figure 14 presents the impact of a common sector-specific shock on sectoral output growth (for each sector) across 13 countries. The impulse responses of the IRBC model closely match the impulse responses of the FAVAR model for 15 different shocks (each representing a sector) that are common across countries. The replication of the FAVAR model is highly successful for all sectors when the corresponding 16-84 percentile bands are used, although the initial median impulse responses of construction and communications are relatively less successful. These results suggest that *a common sector-specific productivity shock* can affect sectoral output growth not only directly (through composite good demand) but also through the intermediate inputs purchased from the same sector in all countries.

Figure 15 presents the impact of a country-specific shock on sectoral output growth (for each country) across 15 sectors, with averages taken across sectors. The impulse responses of the IRBC model closely match those of the FAVAR model for 13 different shocks (each representing a country) that are common across sectors. The replication of the FAVAR model is highly successful all sectors when the corresponding 16-84 percentile bands are used, although the initial median impulse responses of Austria, France, Japan, Spain and the United States are relatively more successful. These results suggests that *a country-specific productivity shock* can affect sectoral output growth not only directly (through composite good demand) but also through the intermediate inputs purchased from all sectors in that country.

The IRBC is also successfully replicates the forecast error variance decomposition of sectoral output growth rates obtained by the FAVAR methodology. These results are presented in Appendix C (Figures C1-C4).

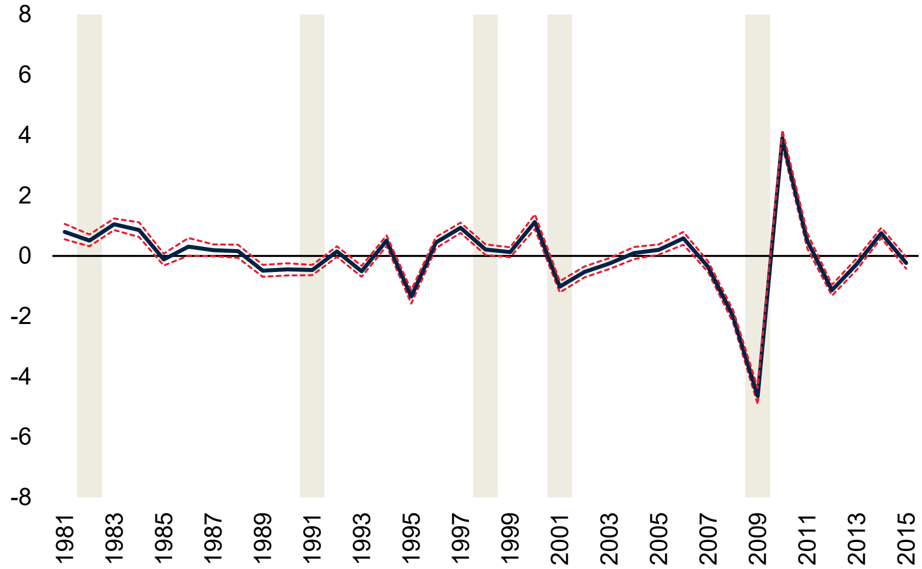
7. Conclusions

We use a dynamic factor model to assess the importance of the global and sector-specific factors in explaining productivity fluctuations across 15 sectors in 13 advanced economies over the past three decades. Additionally, we employ a factor-augmented vector autoregression (FAVAR) model to evaluate the contributions of these factors in accounting for sectoral business cycles. Our findings show that the global and sector-specific factors play a significant role in explaining productivity cycles, suggesting the existence of a global productivity cycle. Together, these factors account for approximately about one-third of the fluctuations observed in sectoral business cycles. The results are consistent with an IRBC model that takes into account input-output linkages across the same 15 sectors and 13 countries and a productivity process that comprises common global, sector-specific and country-specific factors. This consistency suggests that productivity shocks can have an impact on sectoral output growth not only through aggregate linkages but also through input-output linkages across sectors and countries.

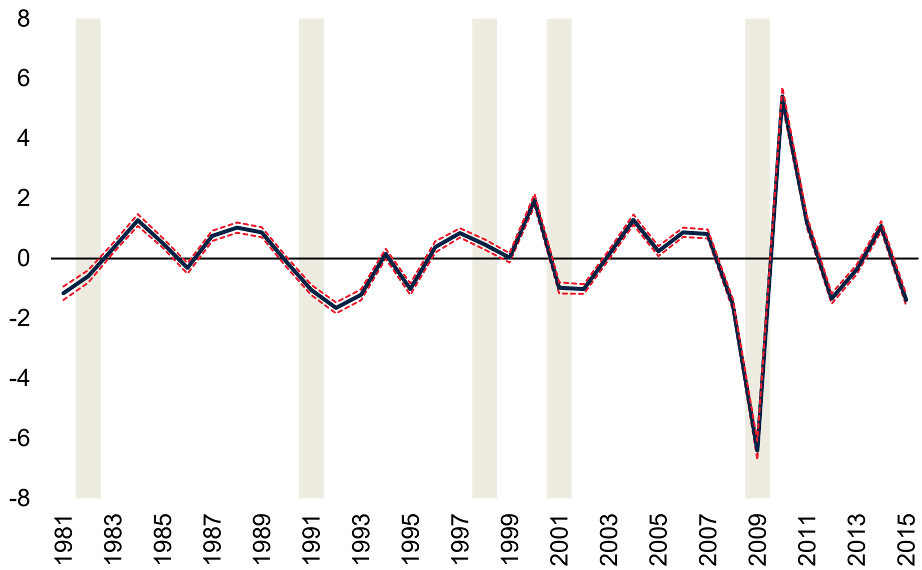
These findings point to three potential directions for future research. First, given the importance of the global and sector-specific factors in explaining business cycles, it would be useful to have a more detailed analysis of firm-level data to analyze how these shocks operate through firm interactions across borders. This could provide deeper insights into the economic mechanisms driving the results. Second, future research can explore the cross-border propagation of sectoral shocks and their interplay with country-specific features. Latly, open economy macroeconomic models should consider productivity processes that account for common global, sector-specific and country-specific drivers.

Figure 1. Global factor

A. Global productivity factor (*Percent*)



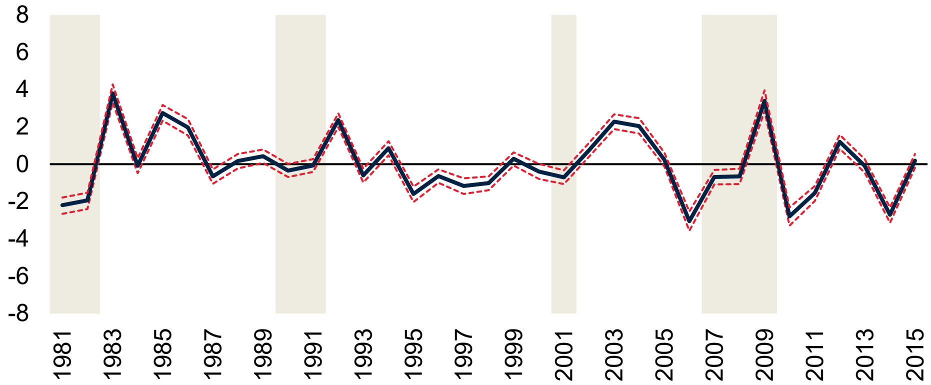
B. Global output factor (*Percent*)



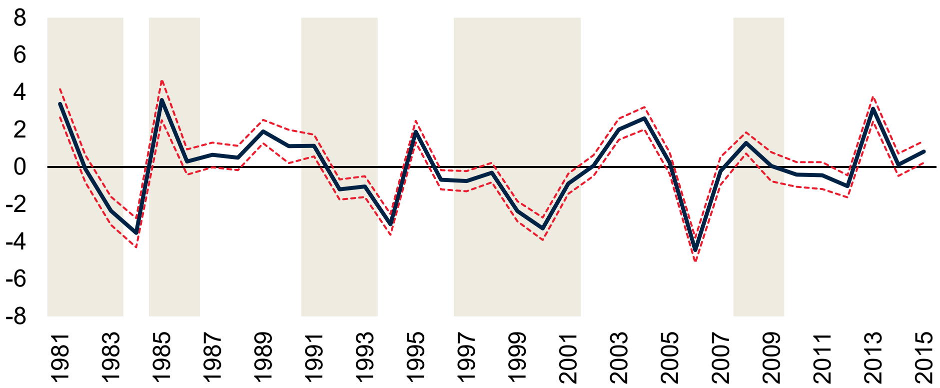
Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: In each panel, we estimate the model over the full sample period for 13 advanced economies and 15 sectors and plot the mean of the posterior distribution of the global factor (blue solid line). The red dashed lines around the mean show 33 and 66 percent quintile bands. Shaded areas show the years of global recessions or slowdowns. Productivity refers to capacity utilization-adjusted TFP.

Figure 2. Country-specific productivity factors

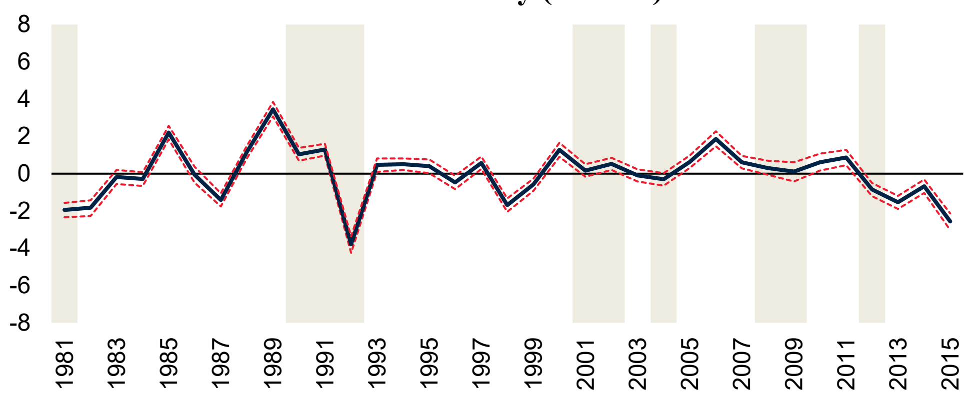
A. United States (*Percent*)



B. Japan (*Percent*)

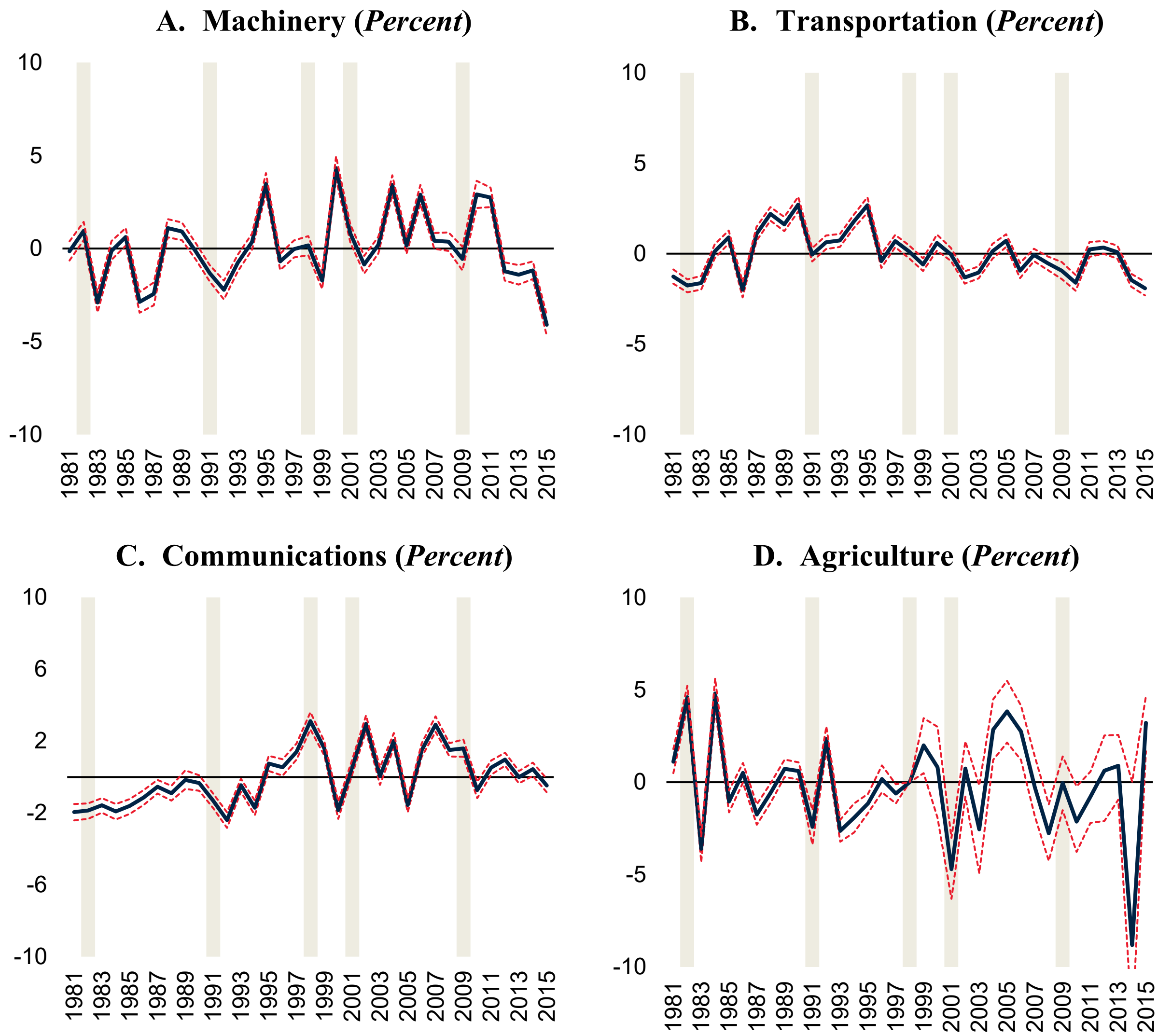


C. Germany (*Percent*)



Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes. In each panel, we estimate the model over the full sample period for 13 advanced economies and 15 sectors and plot the mean of the posterior distribution of the respective country-specific factor (blue solid line). The red dashed lines around the mean show 33 and 66 percent quintile bands. Shaded areas show the years of recessions. Productivity refers to capacity utilization-adjusted TFP.

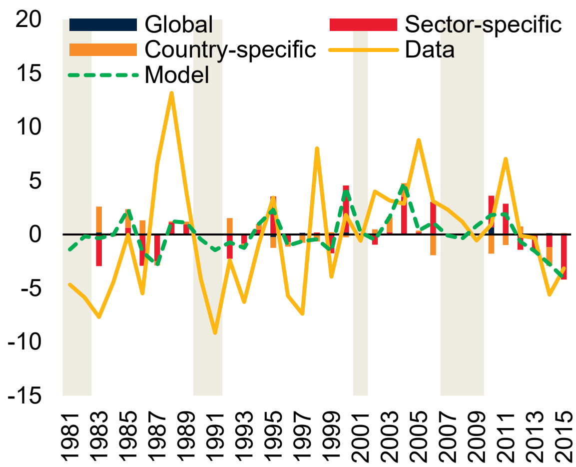
Figure 3. Sector-specific productivity factors



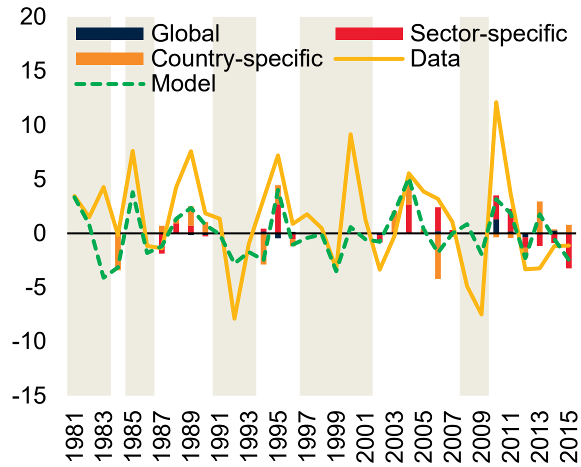
Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: In each panel, we estimate the model over the full sample period for 13 advanced economies and 15 sectors and plot the mean of the posterior distribution of the respective sector-specific factor (blue solid line). The red dashed lines around the mean show 33 and 66 percent quintile bands. Shaded areas show the years of global recessions or slowdowns. Productivity refers to capacity utilization-adjusted TFP.

Figure 4. Productivity growth and estimated factors – Machinery

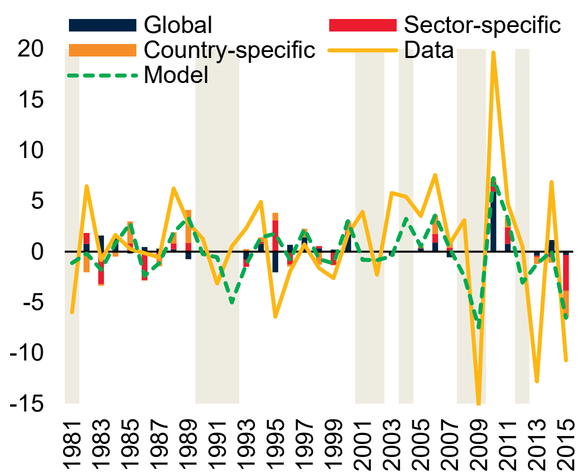
A. United States (*Percent*)



B. Japan (*Percent*)



C. Germany (*Percent*)



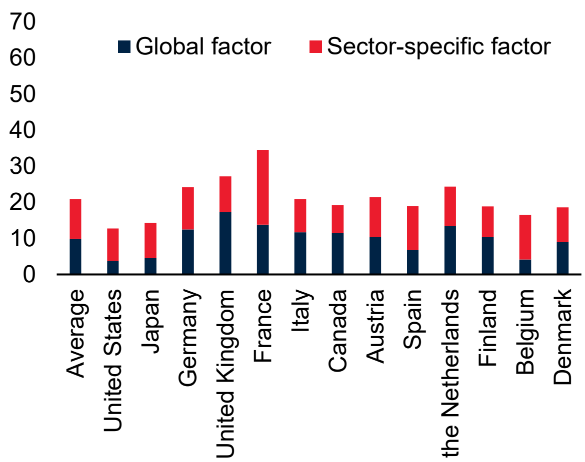
Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: In each panel, we plot the evolution of productivity growth, and the global, sector- and country-specific factors estimated over the full sample period for 13 advanced economies and 15 sectors. To make the scales of the factors and productivity growth comparable, we multiply the mean of the posterior distribution of each factor and the estimated respective factor loading. Global refers to the global factor (blue bars), Sector refers to the sector-specific factors (red bars), Country refers to the country-specific factors (orange bars). Data refers to actual productivity growth (solid yellow line). Model refers to the sum of the contribution of the three factors (dashed green line). Productivity refers to capacity utilization-adjusted TFP. Shaded areas show the years of recessions.

Figure 5. Variance decompositions – Baseline

<u>**Productivity growth**</u>

A. Variance share – Country averages

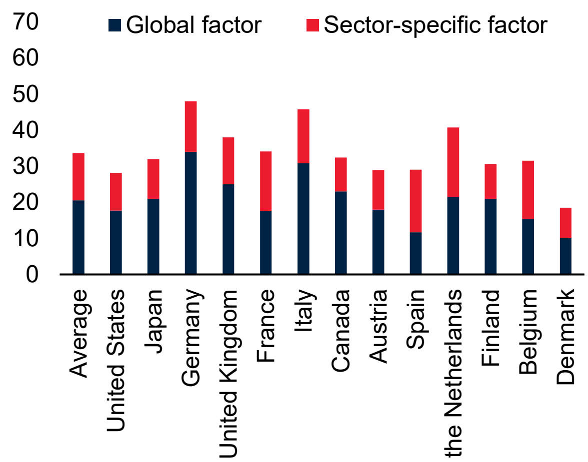
(*Percent*)



<u>**Output growth**</u>

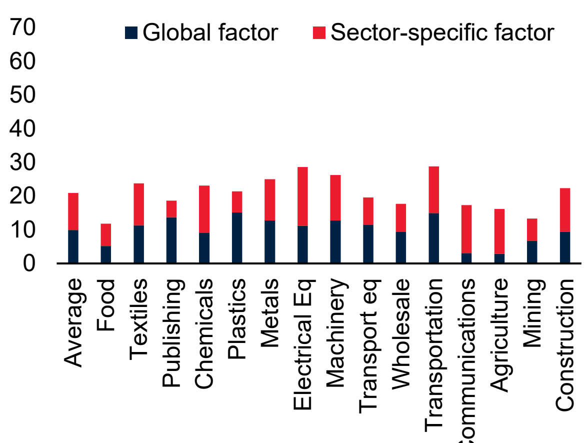
B. Variance share – Country averages

(*Percent*)



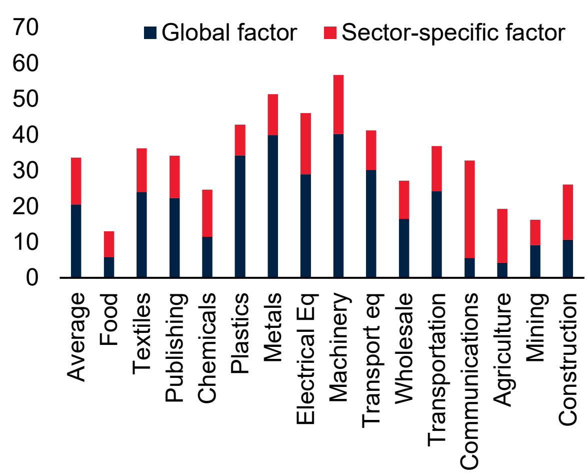
C. Variance share – Sectoral averages

(*Percent*)



D. Variance share – Sectoral averages

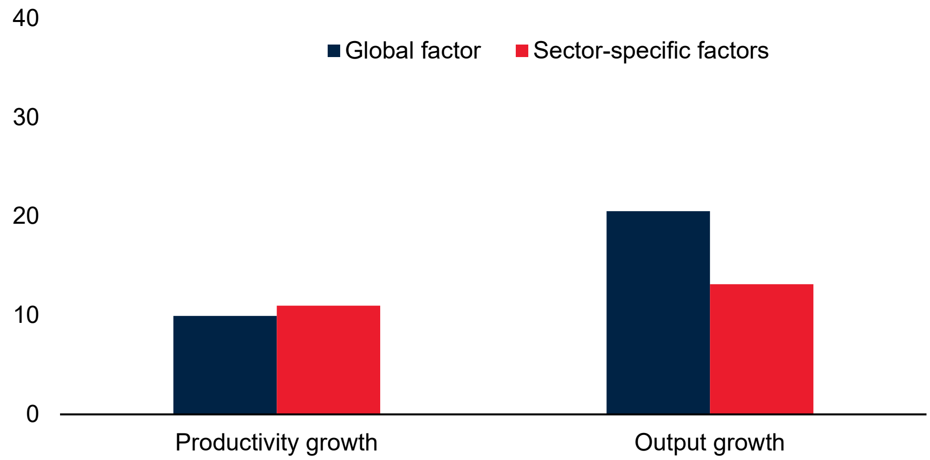
(*Percent*)



Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: In each panel, we estimate the model over the full sample for 13 advanced economies and 15 sectors and plot the unweighted averages across countries/sectors of the percentage of sectoral productivity/output growth fluctuations attributable to the global and sector-specific factors. Productivity refers to capacity utilization-adjusted TFP.

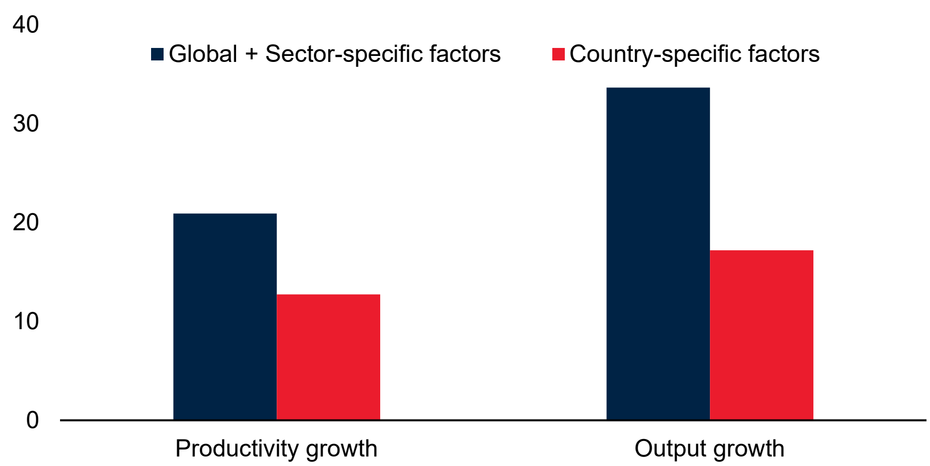
Figure 6. Variance decompositions of productivity growth – Comparisons across factors Global vs Sector-specific factors

(Percent)



A. Common vs Country-specific factors

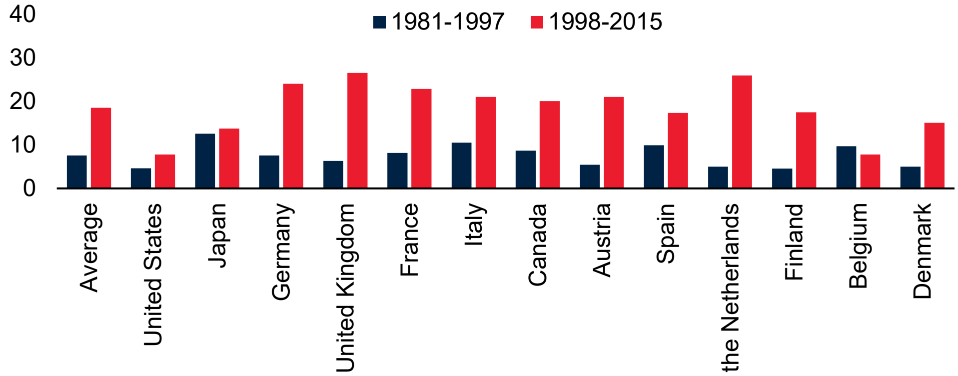
(*Percent*)



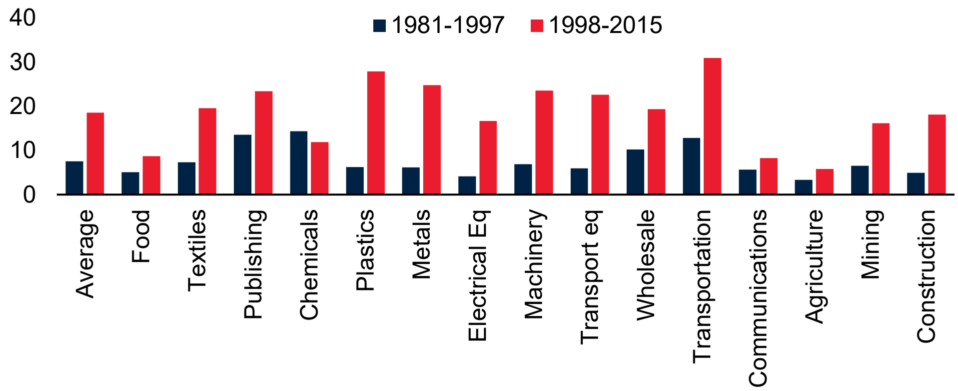
Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: In each panel, we estimate the model over the full sample for 13 advanced economies and 15 sectors and plot the unweighted averages across countries/sectors of the percentage of sectoral productivity/output growth fluctuations attributable to the global and sector-specific factors. Common refers to the sum of Global and Sector-specific factors. Productivity refers to capacity utilization-adjusted TFP.

Figure 7. Variance decompositions of productivity growth over time – Global factor

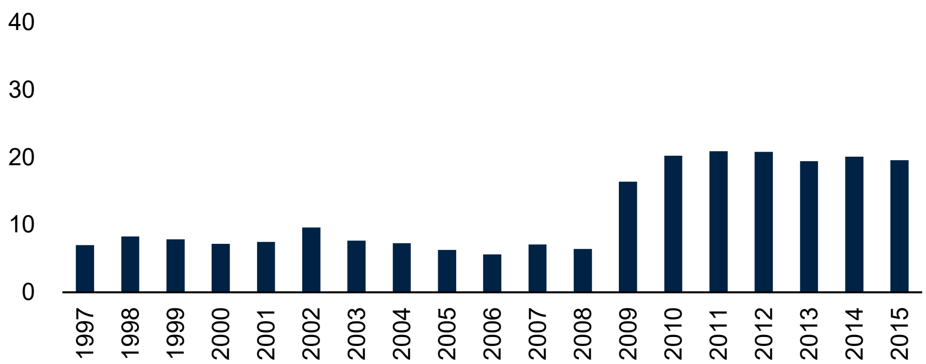
A. Variance share – Country averages (*Percent*)



B. Variance share – Sectoral averages (*Percent*)



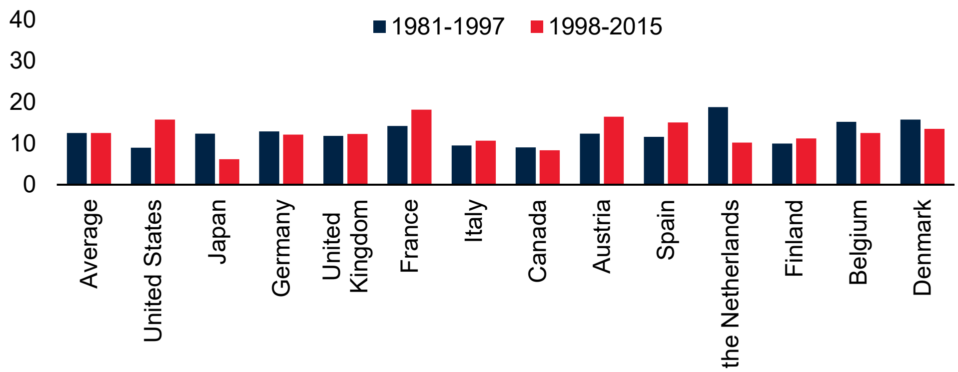
C. Variance share over time – Rolling estimations (*Percent*)



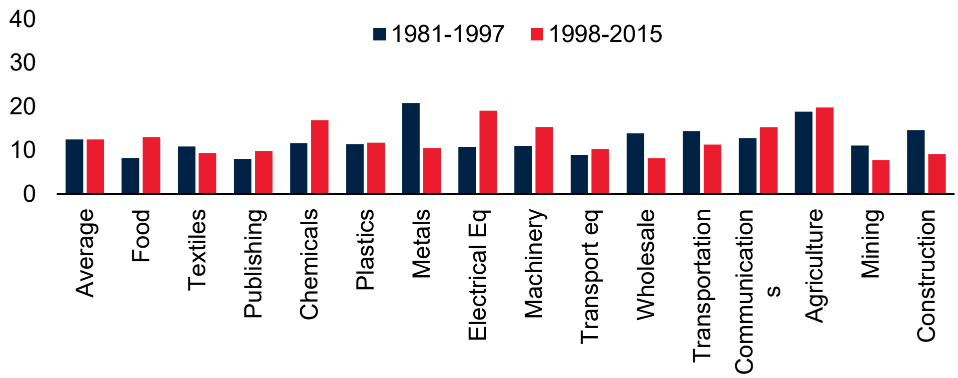
Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: In each panel, we estimate the model over the full sample for 13 advanced economies and 15 sectors and plot the unweighted averages across countries/sectors of the percentage of sectoral productivity/output growth fluctuations attributable to the global and sector-specific factors. Productivity refers to capacity utilization-adjusted TFP.

Figure 8. Variance decompositions of productivity growth over time – Sector-specific factors

A. Variance share – Country averages (*Percent*)



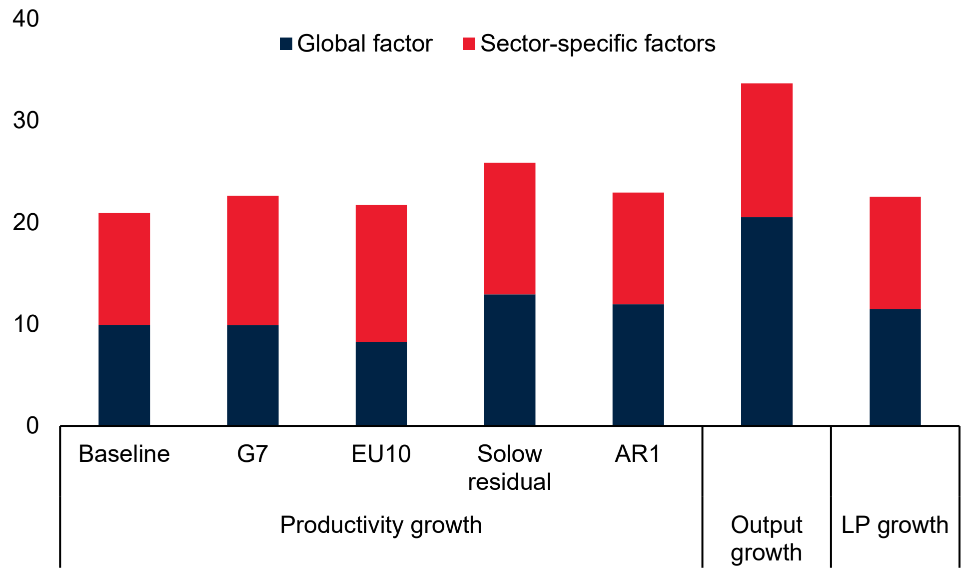
B. Variance share – Sectoral averages (*Percent*)



C. Variance share over time – Rolling estimations (*Percent*)

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: In each panel, we estimate the model over the full sample for 13 advanced economies and 15 sectors and plot the unweighted averages across countries/sectors of the percentage of sectoral productivity/output growth fluctuations attributable to the global and sector-specific factors. Productivity refers to capacity utilization-adjusted TFP.

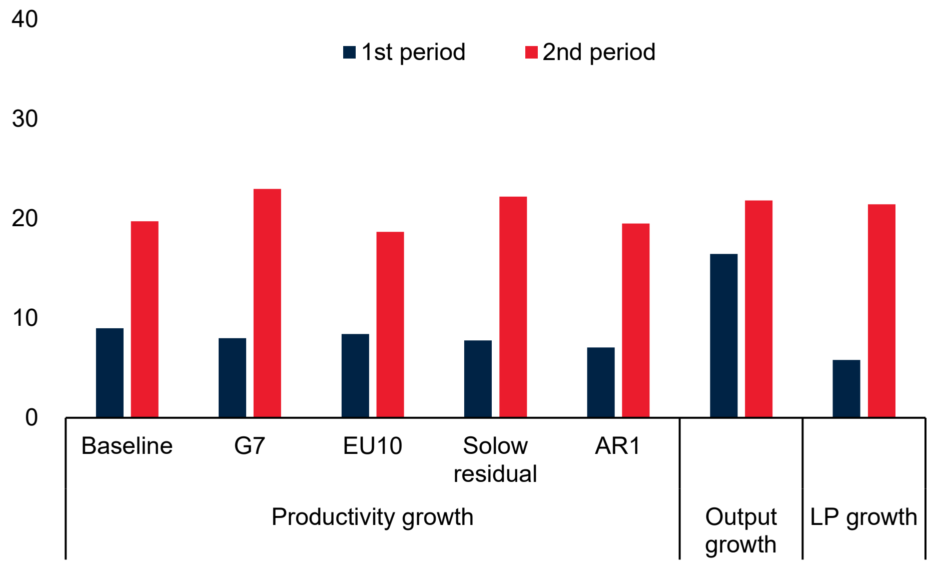
Figure 9. Variance decompositions – Alternative series and specifications
(Percent)



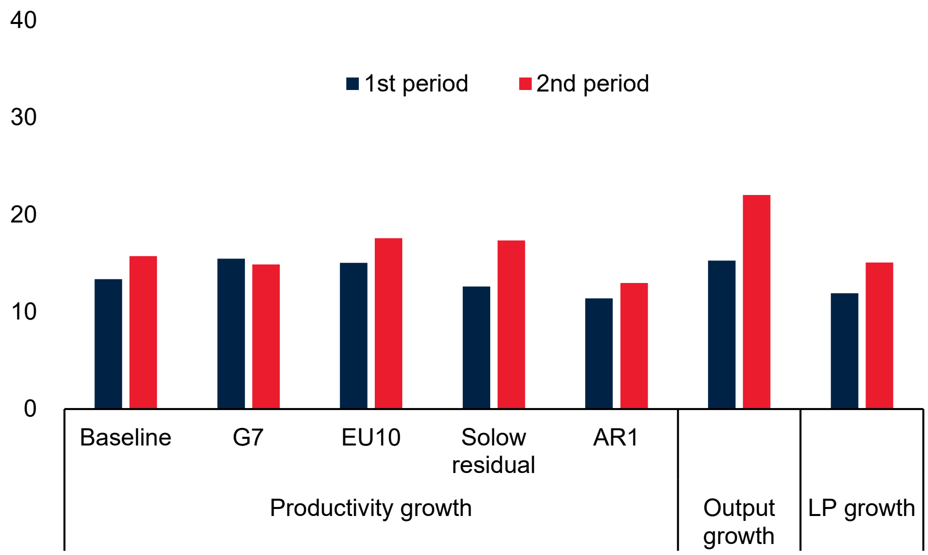
Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: Bars show unweighted averages of sectoral productivity/output/LP fluctuations explained by each factor estimated using a dynamic factor model for 15 sectors. G7 refers to the group of G7 countries. EU10 refers to Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Spain, and United Kingdom. Productivity refers to capacity utilization-adjusted TFP. Solow describes unadjusted residuals. LP refers to labor productivity.

Figure 10. Variance decompositions over time – Alternative series and specifications

A. Global factor (*Percent*)



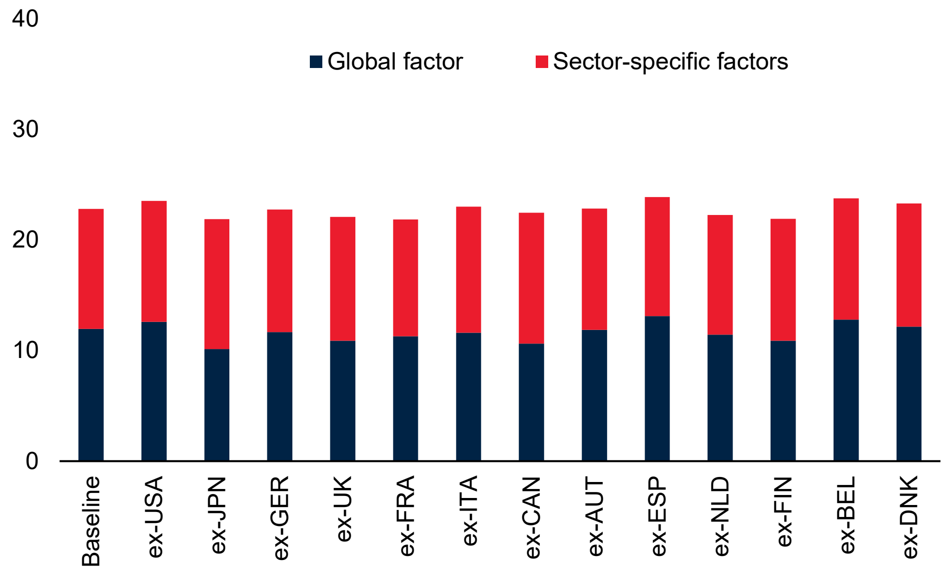
B. Sector-specific factor (*Percent*)



Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: Bars show unweighted averages of sectoral productivity/output/LP growth fluctuations explained by each factor estimated using a dynamic factor model for 15 sectors. G7 refers to the group of G7 countries. EU10 refers to Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Spain, and United Kingdom. Productivity refers to capacity utilization-adjusted TFP. Solow describes unadjusted residuals. LP refers to labor productivity.

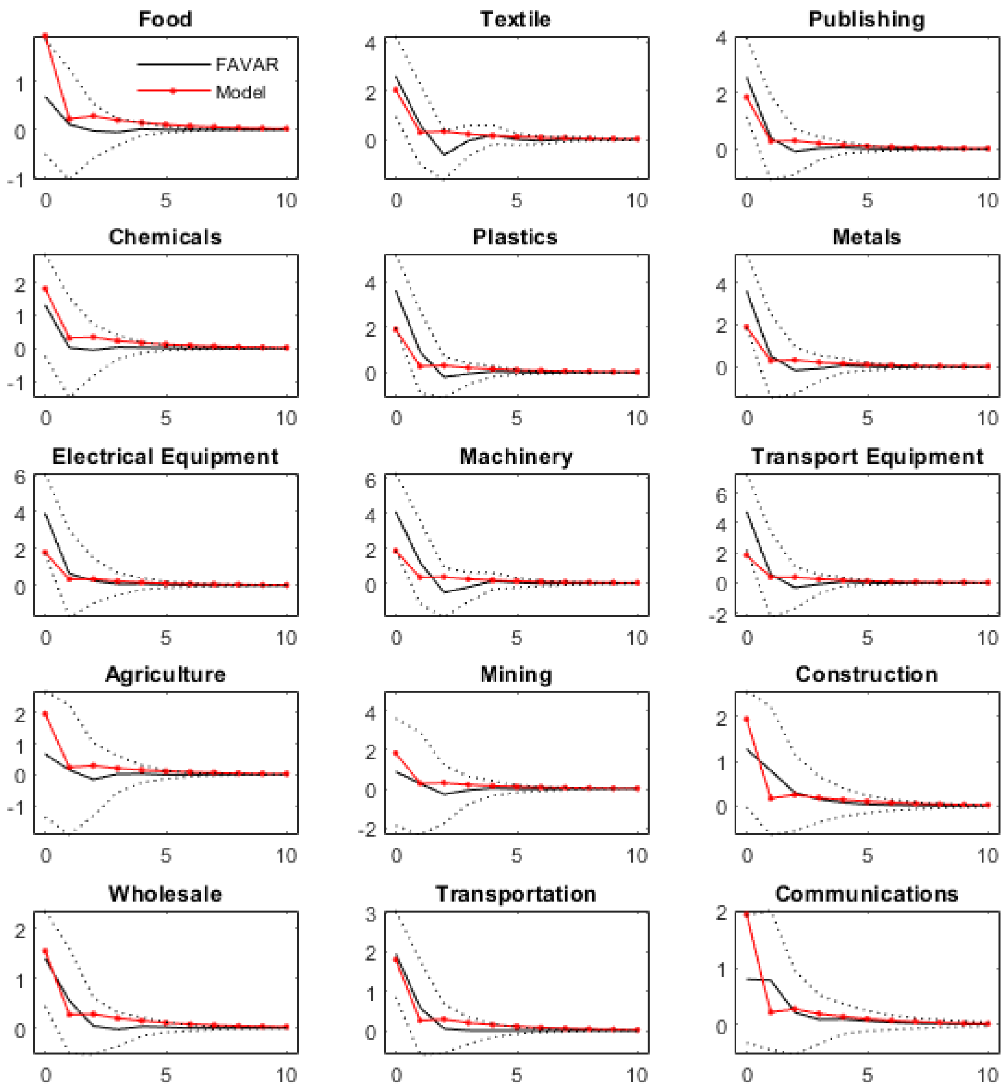
Figure 11. Variance decompositions – Country subgroups

(Percent)



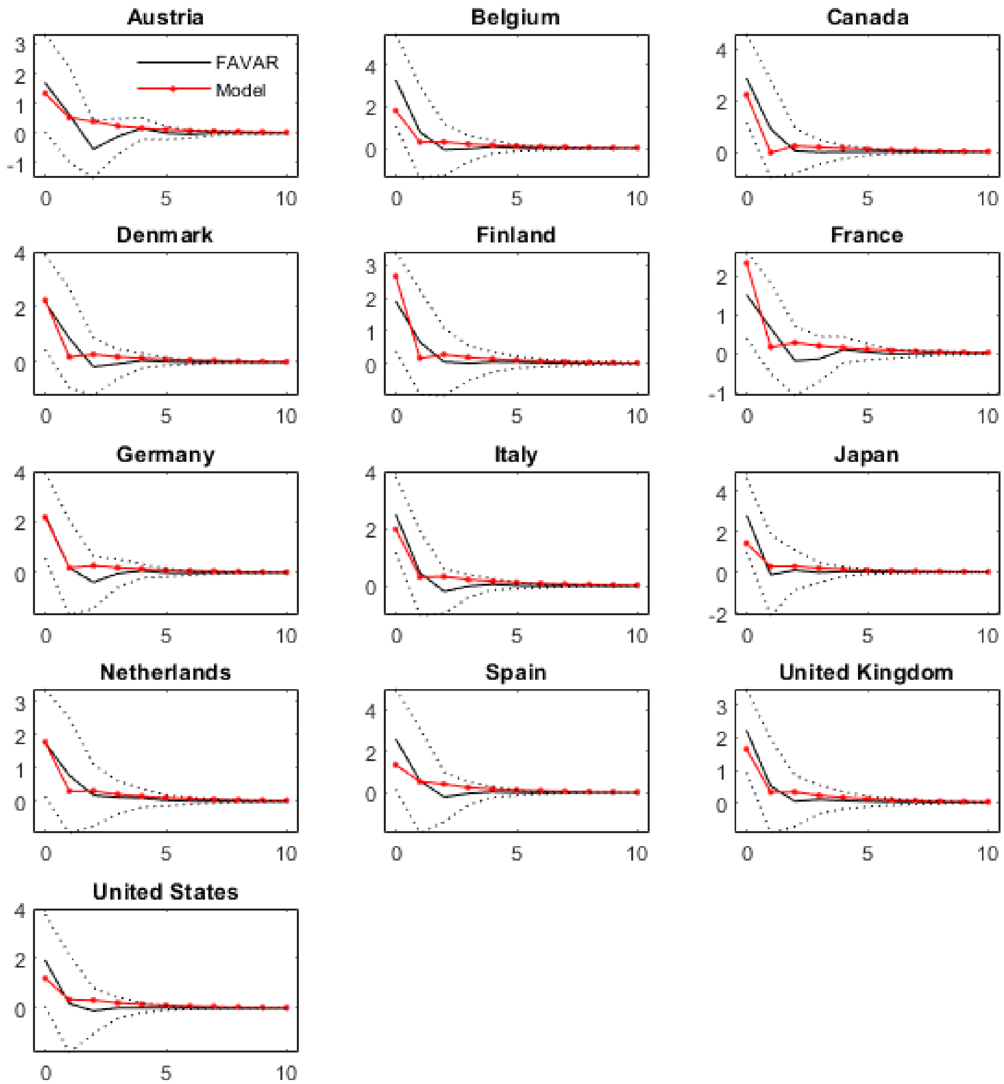
Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: Bars show unweighted averages of sectoral productivity fluctuations explained by each factor estimated using a dynamic factor model for 15 sectors. In each case, the model is estimates while dropping one country from the sample. Productivity refers to capacity utilization-adjusted TFP growth.

Figure 12. Impulse responses of sectoral output growth to a shock in common global productivity factor (averages across countries)



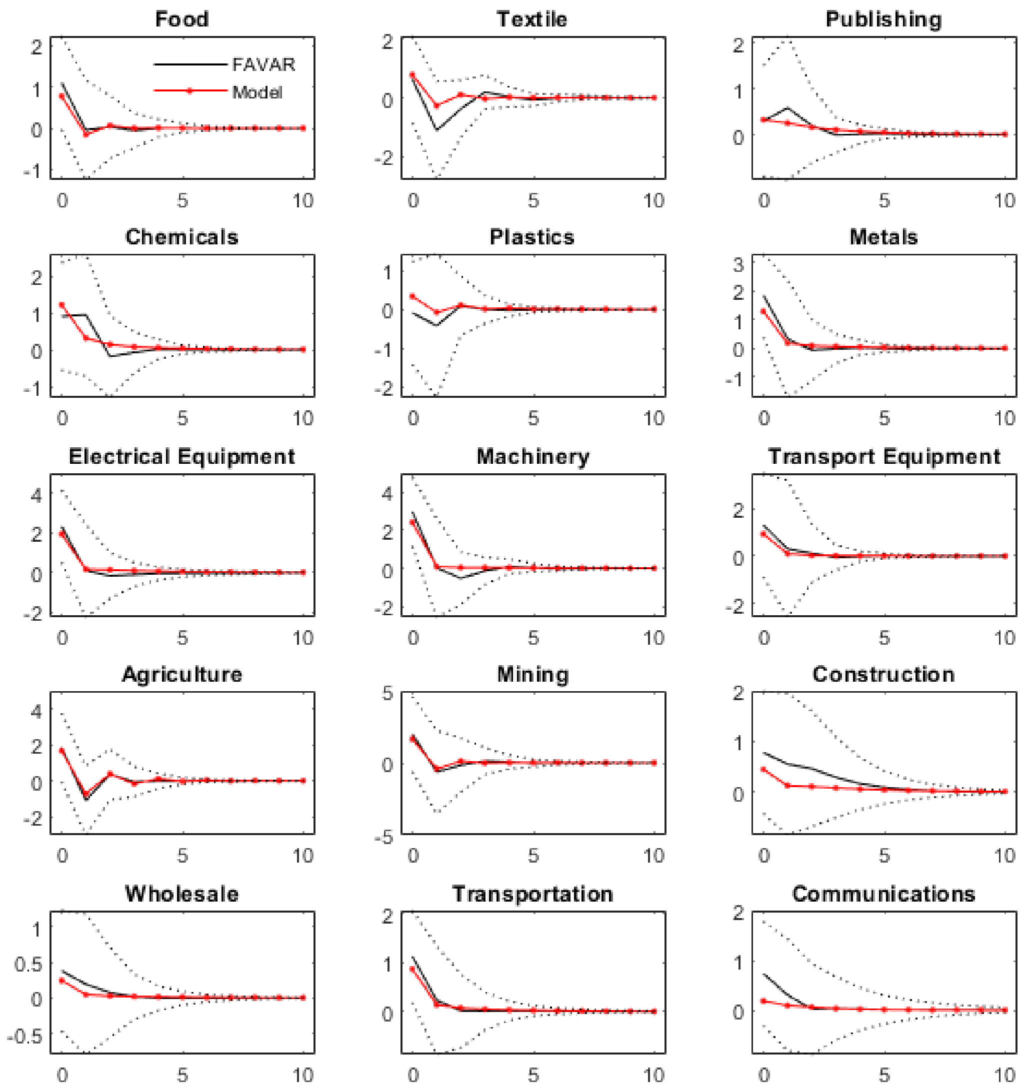
Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: These figures show the median impulse responses of sectoral output growth to a one standard deviation shock of a common global productivity factor. They are represented as averages across sectors. The factors are estimated using a dynamic factor model of 13 countries and 15 sectors. The solid and dashed black lines represent the impulse responses and the corresponding 16-84 percentile bands based on the FAVAR methodology. The solid dotted red lines represent the same impulse responses based on the IRBC model. Productivity refers to capacity utilization-adjusted TFP growth.

Figure 13. Impulse responses of sectoral output growth to a shock of common global productivity factor (averages across sectors)



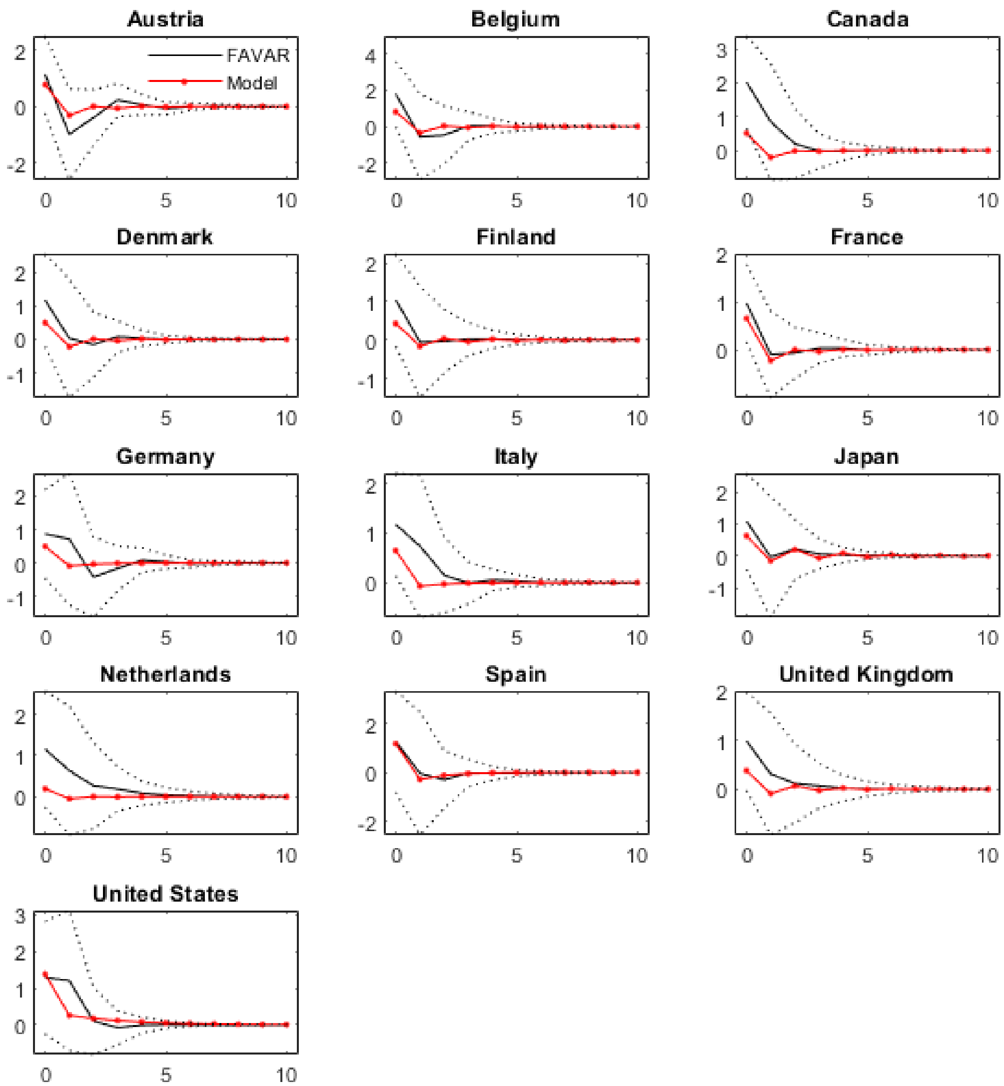
Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: These figures show the median impulse responses of sectoral output growth to a one standard deviation shock of a common global productivity factor. They are represented as averages across sectors. The factors are estimated using a dynamic factor model of 13 countries and 15 sectors. The solid and dashed black lines represent the impulse responses and the corresponding 16-84 percentile bands based on the FAVAR methodology. The solid dotted red lines represent the same impulse responses based on the IRBC model. Productivity refers to capacity utilization-adjusted TFP growth.

Figure 14. Impulse responses of sectoral output growth to a shock in sector-specific productivity factor (averages across countries)



Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: These figures show the median impulse responses of sectoral output growth to a one standard deviation shock of a common sector-specific productivity factor. They are represented as averages across countries. The factors are estimated using a dynamic factor model of 13 countries and 15 sectors. The solid and dashed black lines represent the impulse responses and the corresponding 16-84 percentile bands based on the FAVAR methodology. The solid dotted red lines represent the same impulse responses based on the IRBC model. Productivity refers to capacity utilization-adjusted TFP growth.

Figure 15. Impulse responses of sectoral output growth to a shock in country-specific productivity factor (averages across sectors)



Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: These figures show the median impulse responses of sectoral output growth to a one standard deviation shock of a common sector-specific productivity factor. They are represented as averages across countries. The factors are estimated using a dynamic factor model of 13 countries and 15 sectors. The solid and dashed black lines represent the impulse responses and the corresponding 16-84 percentile bands based on the FAVAR methodology. The solid dotted red lines represent the same impulse responses based on the IRBC model. Productivity refers to capacity utilization-adjusted TFP growth.

Table 1: Variance decompositions for sectoral productivity fluctuations (*Percent*)

	Global+Sector-specific	Global	Sector-specific	Country-specific	Idiosyncratic
Average	20.9	9.9	11.0	12.7	64.6
United States	12.8	3.8	9.0	13.0	72.6
Japan	14.3	4.5	9.8	9.2	74.3
Germany	24.2	12.5	11.7	15.6	58.8
United Kingdom	27.2	17.4	9.8	14.4	56.7
France	34.6	13.8	20.8	12.4	51.6
Italy	20.9	11.7	9.2	18.4	59.4
Canada	19.2	11.5	7.7	20.4	58.9
Austria	21.4	10.4	11.0	10.7	66.2
Spain	19.0	6.8	12.1	12.7	66.8
the Netherlands	24.4	13.4	10.9	11.3	62.6
Finland	18.9	10.3	8.6	8.8	70.3
Belgium	16.6	4.2	12.4	8.1	73.2
Denmark	18.6	8.9	9.7	10.6	69.2
Food	11.8	5.2	6.6	4.1	82.1
Textiles	23.8	11.3	12.4	15.8	59.0
Publishing	18.6	13.7	4.9	23.1	55.4
Chemicals	23.1	9.1	13.9	15.3	60.0
Plastics	21.4	15.1	6.3	28.7	47.4
Metals	25.0	12.7	12.3	17.3	56.3
Machinery	28.6	11.1	17.5	14.3	55.8
Elecrical Eq.	26.2	12.8	13.5	17.5	54.8
Transport Eq.	19.6	11.5	8.1	8.0	70.8
Wholesale	17.7	9.4	8.4	10.9	69.6
Transportation	28.8	15.0	13.8	9.4	60.2
Communications	17.3	3.0	14.3	7.8	73.3
Agriculture	16.2	2.9	13.2	2.7	80.0
Mining	13.3	6.7	6.6	3.3	81.7
Construction	22.4	9.5	12.9	12.6	63.5

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: Each cell shows the unweighted averages across sectors/countries of the variance share of productivity growth attributable to the relevant factor estimated using a dynamic factor model of 13 countries and 15 sectors. Global refers to the global factor, Sectoral refers to each sector-specific factor, Country refers to each country-specific factor, and Idiosyncratic refers to the idiosyncratic factor. Ordering of countries and sectors is the same as in the Table. Productivity refers to capacity utilization-adjusted TFP growth.

Table 2: Variance decompositions for sectoral output fluctuations *(Percent)*

	Global+Sector-specific	Global	Sector-specific	Country-specific	Idiosyncratic
Average	33.7	20.5	13.2	17.2	48.3
United States	28.1	17.7	10.4	19.7	51.5
Japan	31.9	21.0	10.9	18.4	48.8
Germany	48.0	34.0	14.0	10.3	40.9
United Kingdom	38.0	25.0	13.0	18.8	42.6
France	34.1	17.5	16.6	19.9	45.1
Italy	45.8	30.8	15.0	13.3	40.2
Canada	32.4	23.0	9.4	32.1	35.0
Austria	28.9	17.9	11.0	12.7	57.2
Spain	29.0	11.7	17.4	19.7	50.5
the Netherlands	40.8	21.5	19.3	13.1	45.3
Finland	30.6	21.0	9.6	18.8	49.8
Belgium	31.5	15.4	16.2	12.0	55.4
Denmark	18.5	10.1	8.4	14.7	66.0
Food	13.0	5.9	7.1	9.6	76.2
Textiles	36.2	24.0	12.3	22.3	40.8
Publishing	34.2	22.3	11.8	29.4	35.5
Chemicals	24.7	11.5	13.2	15.6	59.0
Plastics	42.9	34.2	8.6	33.9	22.3
Metals	51.4	39.9	11.5	16.8	31.1
Machinery	46.1	29.0	17.1	16.3	37.1
Elecrical Eq.	56.7	40.3	16.5	18.3	24.5
Transport Eq.	41.3	30.2	11.1	12.3	45.7
Wholesale	27.2	16.6	10.7	24.6	47.2
Transportation	36.9	24.2	12.7	18.0	44.3
Communications	32.8	5.6	27.2	12.2	54.4
Agriculture	19.3	4.3	15.1	2.9	77.1
Mining	16.2	9.2	7.1	4.1	78.5
Construction	26.1	10.7	15.4	21.7	51.2

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: Each cell shows the unweighted averages across sectors/countries of the variance share of output growth attributable to the relevant factor estimated using a dynamic factor model of 13 countries and 15 sectors. Global refers to the global factor, Sectoral refers to each sector-specific factor, Country refers to each country-specific factor, and Idiosyncratic refers to the idiosyncratic factor. Ordering of countries and sectors is the same as in the Table.

Table 3: Share of sectoral output explained by productivity factors *(Percent)*

	Global			Sector-specific			Country-specific		
years	1	5	10	1	5	10	1	5	10
Average	**24.1**	**24.8**	**24.8**	**10.7**	**12.6**	**12.6**	**10.5**	**12.3**	**12.3**
United States	23.1	21.5	21.5	9.0	11.7	11.7	10.9	14.5	14.5
Japan	24.8	23.7	23.7	9.6	11.5	11.6	5.6	8.0	8.0
Germany	31.5	28.3	28.3	11.3	13.6	13.6	5.8	9.9	9.9
United Kingdom	33.1	32.7	32.6	7.3	9.2	9.3	10.7	13.0	13.0
France	23.1	28.0	28.0	20.6	19.6	19.6	15.2	12.8	12.8
Italy	34.9	32.3	32.3	7.2	10.3	10.3	9.4	13.3	13.4
Canada	26.9	26.3	26.3	8.5	12.1	12.1	13.8	14.3	14.3
Austria	15.3	17.6	17.6	12.3	13.5	13.5	11.2	14.2	14.2
Spain	16.0	18.3	18.3	8.4	11.7	11.7	10.5	12.2	12.2
the Netherlands	23.8	27.7	27.7	12.1	14.8	14.8	10.1	10.4	10.4
Finland	26.1	26.0	26.0	10.4	10.8	10.8	12.0	14.6	14.6
Belgium	17.7	21.2	21.2	11.9	13.9	14.0	11.0	11.1	11.1
Denmark	16.5	18.8	18.8	10.8	11.3	11.3	10.7	12.2	12.2
Food	8.8	9.4	9.4	12.4	14.5	14.5	5.8	7.7	7.7
Textiles	26.4	27.9	27.9	6.5	11.2	11.3	13.9	15.1	15.1
Publishing	31.0	30.9	30.9	4.5	6.8	6.8	21.5	23.3	23.3
Chemicals	12.2	13.4	13.4	12.1	17.4	17.4	16.2	17.3	17.3
Plastics	43.7	44.0	44.0	5.4	6.9	6.9	17.4	17.8	17.8
Metals	37.8	34.8	34.8	12.3	13.0	13.0	9.8	12.5	12.6
Machinery	34.5	34.2	34.2	13.7	14.1	14.1	9.2	9.7	9.7
Electrical Eq	34.7	35.1	35.1	17.7	17.0	17.0	10.9	14.5	14.5
Transport Eq	37.2	34.3	34.3	5.6	6.9	6.9	6.1	11.3	11.3
Agriculture	6.7	9.4	9.4	16.4	15.7	15.7	3.7	5.3	5.3
Mining	8.1	10.1	10.1	11.0	13.6	13.6	3.3	5.1	5.1
Construction	13.6	18.0	18.0	8.4	12.1	12.2	15.3	16.3	16.3
Wholesale	25.3	26.4	26.4	11.2	12.5	12.5	10.8	12.2	12.2
Transport	32.3	31.2	31.2	11.8	13.0	13.0	7.6	9.4	9.4
Communications	8.8	12.9	12.9	12.0	14.6	14.7	6.4	7.6	7.6

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: Each cell shows the unweighted averages of the proportion of forecast error variance explained by each factor estimated using a FAVAR methodology. Global refers to the global factor, Sector refers to each sector-specific factor, Country refers to each country-specific factor.

Table 4: Share of sectoral output explained by productivity factors – By sector *(Percent)*

	Global			Sectoral			Country		
years	1	5	10	1	5	10	1	5	10
				United States					
Machinery	28.8	23.7	23.7	11.9	12.6	12.6	0.1	12.4	12.4
Transportation	28.0	25.5	25.5	2.3	2.2	2.2	23.5	28.6	28.6
Communications	1.8	1.4	1.4	17.2	24.6	24.6	4.7	3.5	3.5
Agriculture	0.7	1.2	1.2	12.2	17.1	17.1	1.7	4.1	4.1
				Japan					
Machinery	39.7	39.9	39.9	16.6	16.4	16.4	11.8	11.6	11.6
Transportation	28.0	25.5	25.5	2.3	2.2	2.2	23.5	28.6	28.6
Communications	3.7	3.3	3.3	2.2	17.4	18.3	1.2	0.7	0.8
Agriculture	1.0	3.7	3.7	14.8	14.8	14.8	5.9	5.3	5.3
				Germany					
Machinery	46.5	33.3	33.2	21.6	16.0	15.9	3.3	16.5	16.5
Transportation	8.9	10.2	10.2	9.4	21.8	21.8	16.0	14.9	14.9
Communications	2.4	18.9	18.9	36.8	29.9	29.9	0.3	2.6	2.6
Agriculture	10.0	9.4	9.4	26.2	27.2	27.2	0.1	0.3	0.3

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: Each cell shows the proportion of forecast error variance explained by each factor estimated using a FAVAR methodology. Global refers to the global factor, Sector refers to each sector-specific factor, Country refers to each country-specific factor.

Table 5: Share of sectoral output explained by productivity factors over time *(Percent)*

	Global			Sector-specific		
years	**1981-2015**	**1981-1997**	**1998-2015**	**1981-2015**	**1981-1997**	**1998-2015**
Average	**24.1**	**10.3**	**39.1**	**10.7**	**10.3**	**12.0**
United States	23.1	18.0	33.3	9.0	11.7	11.7
Japan	24.8	6.4	45.2	9.6	18.7	8.8
Germany	31.5	9.3	48.6	11.3	17.1	8.8
United Kingdom	33.1	14.9	38.2	7.3	12.8	12.3
France	23.1	4.4	39.3	20.6	25.0	20.7
Italy	34.9	11.1	53.6	7.2	14.8	8.0
Canada	26.9	10.7	48.6	8.5	15.3	8.9
Austria	15.3	8.8	38.4	12.3	9.7	15.8
	16.0	6.2	29.3	8.4	11.2	14.9
Netherlands	23.8	8.2	37.5	12.1	18.0	13.8
Finland	26.1	17.1	33.1	10.4	14.4	14.8
Belgium	17.7	6.5	34.9	11.9	21.2	8.1
Denmark	16.5	12.1	28.8	10.8	18.6	8.9
Food	8.8	9.0	17.0	12.4	9.0	16.7
Textiles	26.4	10.7	41.0	6.5	10.7	11.5
Publishing	31.0	19.1	50.5	4.5	19.1	7.6
Chemicals	12.2	15.8	16.8	12.1	15.8	15.4
Plastics	43.7	13.2	61.4	5.4	13.2	2.7
Metals	37.8	6.0	61.4	12.3	6.0	4.9
Machinery	34.5	9.2	44.8	13.7	9.2	21.8
Electrical Eq	34.7	4.6	62.7	17.7	4.6	12.9
Transport Eq	37.2	10.4	59.2	5.6	10.4	7.1
Agriculture	6.7	5.5	14.5	16.4	5.5	20.7
Mining	8.1	5.7	16.2	11.0	5.7	18.0
Construction	13.6	15.0	30.2	8.4	15.0	9.6
Wholesale	25.3	13.5	38.1	11.2	13.5	8.5
Transport	32.3	7.4	52.6	11.8	7.4	8.1
Communications	8.8	9.0	20.5	12.0	9.0	14.0

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: Each cell shows the unweighted averages of the proportion of forecast error variance explained by each factor estimated using a FAVAR methodology. Global refers to the global factor, Sector refers to each sector-specific factor, Country refers to each country-specific factor.

Appendix A: Database

Construction of the database. The data required for estimating sectoral productivity growth are real output and real inputs for a panel of countries, sectors, and years. The dataset with the broadest coverage of this information is World KLEMS (O'Mahoney and Timmer, 2009). This database contains value added, labor and capital inputs, as well as value added and input deflators. The database covers all sectors of the economy at a level slightly more aggregated than the 2-digit ISIC revision 4. An advantage of using this dataset is that it provides consistent measures of capital and labor input that are harmonized across sectors and countries, allowing for the construction of consistent measures of productivity.

We compare output and productivity growth series of World KLEMS 2019 vintage dataset with country-specific sources for the United States and Canada for "Machinery" and "Rubber and plastics products, and other non-metallic mineral products" manufacturing sectors. The definition of "Machinery" sector in the national sources corresponds to the one in KLEMS. "Rubber and plastics products, and other non-metallic mineral products" sector, on the other hand, is reported as one sector in KLEMS, whereas is subdivided in two sectors, namely "Rubber and plastics" and "other non-metallic mineral", in the national accounts. We calculate the average growth rate of these two sectors from the national accounts.[32] The series available in World KLEMS closely follow the series available from the respective statistical agencies (Figures A1-A2). More broadly, the correlations of output and productivity growth between the series provided by World KLEMS and country-specific sources for United States and Canada are high (very close to 1), suggesting that KLEMS data closely reflects movements in these series as captured by country-specific sources.

We increase the time series coverage of our dataset by combining various vintages of the KLEMS database. Specifically, the 2019 release of KLEMS provides data until 2015.[33] Unfortunately, this update provides data for capital and labor inputs only as far back as 1996, with some variations across countries and sectors. Previous updates released in 2012 and 2011 provide data that can extend these series backwards to 1981. Table A2 provides basic statistics about growth rate of real value added from each vintage. The data appears to be comparable across sources, with very similar first and second order moments across vintages.

[32] Similar differences exist in the aggregation of sectors across vintages of KLEMS. For the United States, for example, the 2017 vintage reports "Rubber and plastics products, and other non-metallic mineral products" as one sector. Previous vintages, similar to national accounts, report two separate sectors ("Rubber and plastics" and "other non-metallic mineral").

[33] In principle, the data extend until 2017 for the United States and most European countries, but are available only until 2016 for United Kingdom and until 2016 for Japan. Additionally, missing data for factor inputs allows for consistent data for the economies in our sample only until 2015. We complement the KLEMS dataset with harmonized data from Statistics Canada.

The latest vintage of KLEMS does not include Canada, so we extend the data to include Canada using data from country-specific sources and earlier versions of World KLEMS. First, multifactor productivity database was downloaded from Statistics Canada.[34] The industry classification of this database uses the North American Industry Classification (NAICS). This classification was translated to NACE1 code (Statistical Classification of Economic Activities in the European Community) and to NACE2 code that is the latest version available of NACE1. By using NACE classification, the Statistics Canada database is harmonized with World KLEMS and EU KLEMS data. Second, we used information on workers and hours from Statistics Canada Employment dataset and earlier vintages of KLEMS.[35]

To harmonize the data across vintages, we first use the sector-specific price indices of each input to re-construct real variables that refer to the same base year – 2010.[36] Then, we re-group sectors by summing the constructed real values if there are any differences in the aggregation of sectors across vintages. Finally, we use growth rates of these harmonized real variables to extend the latest vintage backward for the period 1981-2015. Once treated, real output and capital input growth rates appear to be similar across vintages. This allows us to confidently extend the dataset.[37] Table A4 provides more details on how the sectors in each vintage are matched to harmonize and extend the dataset to produce a balanced dataset.

In the end, we compile a dataset on productivity growth that is adjusted for capacity utilization for as many as 26 sectors for 13 countries for the period 1981-2015. While previous studies on productivity comovement focus only on manufacturing, we also utilize other goods- and services-producing sectors in our analysis. Following the BEA's definition, the goods-producing sectors comprise: agriculture; mining; construction; and manufacturing. The services-producing sectors comprise: utilities; wholesale and retail trade; transportation and storage; information and communications; finance, insurance, real estate, rental, and leasing; professional and business services; educational services, health care, and social assistance; arts, entertainment, recreational, accommodation, and food services; and other services (except public administration).

For our baseline results, we focus on a subset of sectors that are large and trade the most inputs with the other countries in our sample. Within manufacturing, our database includes all sectors

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[34] DOI (Jan 27,2020)" https://doi.org/10.25318/3610021701-eng

[35] Employment and hour by industry in Statistics Canada website is available for the 1997-2018 period. We complemented each sectoral series with data from the 2012 vintage of World KLEMS.

[36] One should pay close attention when using these data as for some countries data is filled-in using information from earlier vintages without adjusting for the same base year. Examples include Germany and United Kingdom. We re-construct real values for all variables using earlier vintages and do not use the filled-in (light gray) values in the latest World KLEMS. Gordon and Sayed (2019) describe some issues with United Kingdom data in the 2017 vintage.

[37] Our methodology is similar to Gordon and Sayed (2019).

that, on average, either account for more than one percent of the economy's total output during the 2000-15 period, or import inputs valued at least one percent of sectoral output from the other countries in the sample.[38] Within services-producing sectors, our dataset includes all the sectors that import inputs valued at least 0.1 percent of sectoral output from the other countries in the sample.[39] In total, the database includes 15 sectors.[40]

Adjustment for capacity utilization. Following the standard literature, productivity is estimated using Solow residuals for each sector. As is well-known, standard, residual-based measures of productivity tend to include unobserved input utilization, which exhibits cyclical behavior and can spuriously capture comovement. Following Basu et al. (2006), the sector-specific estimated residuals are adjusted for capacity utilization using hours per worker to correct for increased effort during the business cycle. More specifically, for each sector s in country c, we estimate:

$$dva_{c,s,t} = \gamma_{c,s} dx_{c,s,t} + \beta_{c,k} du_{c,s,t} + z_{c,s,t} \qquad (A1)$$

where, $dva_{c,s,t}$ refers to value added growth and already accounts for material inputs; $du_{c,s,t}$ denotes growth in unobserved inputs measured by (per worker) hours worked; and $z_{c,s,t}$ refers to total factor productivity growth (adjusted for capacity utilization). $dx_{c,s,t}$ is growth in observed input, and is computed as:

$$dx_{c,s,t} = s^{l}_{c,s,t} dl_{c,s,t} + s^{k}_{c,s,t} dk_{c,s,t} \qquad (A2)$$

Where, $dl_{c,s,t}$, $dk_{c,s,t}$ denote growth in employment and capital, respectively, and $s^{l}_{c,s,t}$ and $s^{k}_{c,s,t}$ refer to ratios of payments to labor and capital, in total cost, respectively. All inputs and ratios to

[38] Results are similar when averaging over the 2010-15 period. To measure openness to trade in intermediate goods, we utilize data from the 2014 World Input-Output Table. The manufacturing sectors included in our analysis constitute more than 95 percent of total manufacturing production in our sample during the 2000-2015 period. Following the sector aggregation of the latest KLEMS, "Other manufacturing; repair and installation of machinery and equipment (31-33)" is the only sector not included. We do not include "Coke, refined products and nuclear fuel (19)" because it is very volatile (standard deviation is a multiple of other sectors in most countries).

[39] The service-producing sectors participate less in global value chains and 0.1 cut-off corresponds to the 80th percentile of all market services in terms of openness to trade. The sectors excluded are: Electricity, Gas and Water Supply (D-E), Accommodation and Food Service Activities (I), Financial and Insurance Activities (K), and Arts, Entertainment, Recreation and Other Service Activities (R-S). We also exclude non-market services (Real Estate Activities (L), Public Administration (O), Education (P), and Health and Social Work (Q)).

[40] These sectors and the respective codes (in parenthesis) following the 2017 release of the KLEMS database are: Food products, Beverages and Tobacco (10-12); Textiles, Wearing apparel, Leather and related products (13-15); Wood and Paper products, Printing and Reproduction of recorded media (16-18); Chemicals and Chemical products (20-21); Rubber and Plastic products (22-23); Basic metal and Fabricated metals (24-25); Electrical and Optical equipment (26-27); Machinery and Equipment (28); Transport equipment (29-30); Agriculture, Forestry and Fishing (A); Mining and Quarrying (B); Construction (F); Wholesale and Retail trade, Repair of motor vehicles and motorcycles (G); Transportation and Storage (H); Information and Communications (J). The activity in these sectors constitutes about 70 percent of the market economy in our sample during the 2000-2015 period.

payments to labor and capital are taken from KLEMS. Equation (A1) is estimated using OLS regressions.

Table A1. Real output across datasets

	KLEMS 2011		KLEMS 2012		KLEMS 2017		KLEMS 2019	
	Mean	**St. Dev**	**Mean**	**St. Dev**	**Mean**	**St. Dev**	**Mean**	**St. Dev**
United States	3.48	4.98	3.16	6.29	3.12	5.20	2.51	7.48
Japan	2.53	4.57	1.84	5.41			1.29	7.78
Germany	1.88	4.22	1.91	5.71	2.09	5.56	1.07	7.05
United Kingdom	3.12	3.72	2.43	4.41	2.49	4.98	1.07	5.35
France	2.57	3.86	2.10	3.50	2.11	3.46	1.26	4.82
Italy	1.98	3.30	1.45	3.95	1.40	4.37	1.25	5.21
Canada	2.48	4.28	2.92	4.78			1.87	6.61
Austria	2.91	4.20	2.46	4.59	2.36	4.68	1.81	6.39
Spain	3.35	4.43	2.89	4.66	2.24	5.53	1.85	6.27
Netherlands	3.17	4.19	2.75	4.68	2.70	4.96	2.02	6.05
Finland	4.23	6.64	3.24	8.14	2.97	7.59	2.38	8.93

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: Output growth. Each cell represents the GDP-weighted average of sectoral output growth for the 15 sectors in our baseline for each country. KLEMS 2011, 2012, and 2017 refer to the 2011, 2012, 2017, and 2019 vintages of EU and World KLEMS, respectively.

Table A2. Capital and Labor across vintages of KLEMS

	Austria	Finland	France	Germany	Italy	Japan	Netherlands	Spain	United Kingdom	United States
						Labor				
Food	1.00	0.99	0.97	0.14	1.00	0.64	0.53	0.99	1.00	0.74
Textiles	1.00	1.00	1.00	0.90	1.00	0.55	0.83	1.00	1.00	-0.22
Publishing	1.00	1.00	1.00	0.80	1.00	0.79	0.82	1.00	1.00	0.99
Chemicals	0.99	0.99	0.92	0.62	0.91	0.57	0.67	1.00	1.00	0.86
Plastics	0.99	0.99	1.00	0.59	1.00	0.80	0.76	1.00	1.00	0.99
Metals	1.00	0.98	1.00	0.53	1.00	0.78	0.61	1.00	1.00	0.99
Electrical Eq	0.99	0.96	1.00	0.52	0.96	0.73	0.70	1.00	1.00	0.94
Machinery	0.99	0.96	0.98	0.26	1.00	0.86	0.00	1.00	0.99	0.98
Transport Eq	1.00	0.38	0.99	0.59	0.99	0.63	0.61	1.00	1.00	0.94
Agriculture	1.00	1.00	1.00	0.70	1.00	-0.41	0.33	1.00	0.96	0.92
Mining	1.00	0.73	1.00	0.90	0.62	-0.01	0.65	0.92	0.97	0.94
Construction	0.99	1.00	0.99	0.61	1.00	0.42	0.11	1.00	1.00	1.00
Wholesale	1.00	0.99	1.00	0.35	1.00	0.40	-0.02	1.00	0.99	0.92
Transportation	0.98	0.73	1.00	0.16	0.99	-0.03	-0.10	1.00	1.00	0.95
Communication	1.00	1.00	1.00	0.10	1.00	0.25	0.09	1.00	1.00	0.97
						Capital				
Food	-0.98	-0.17	0.77	0.14	1.00	0.27	-0.07	1.00	0.89	-0.31
Textiles	0.84	0.95	0.96	0.54	0.82	-0.15	0.70	0.95	0.99	0.87
Publishing	0.98	0.92	0.98	0.13	-0.95	0.27	0.72	1.00	0.75	0.66
Chemicals	0.48	0.96	0.95	0.07	0.23	0.02	-0.33	1.00	0.48	0.70
Plastics	0.06	0.98	0.98	0.32	-0.68	0.05	-0.15	1.00	0.95	0.81
Metals	0.97	1.00	0.98	0.31	0.98	0.35	0.12	0.95	-0.66	0.50
Electrical Eq	0.82	0.98	0.04	0.24	1.00	0.50	-0.46	1.00	0.76	0.90
Machinery	0.97	0.98	0.92	0.32	0.95	0.61	0.40	1.00	0.75	0.85
Transport Eq	0.81	0.79	0.91	0.24	0.92	0.06	0.66	0.92	-0.18	-0.40
Agriculture	0.91	-0.01	-0.89	0.02	0.96	0.22	0.43	0.94	-0.44	0.60
Mining	0.12	1.00	-0.94	0.49	0.96	-0.02	-0.37	0.53	0.91	-0.12
Construction	-0.65	0.99	1.00	-0.62	0.99	0.15	0.34	1.00	0.98	0.92
Wholesale	0.93	0.68	0.99	0.28	1.00	0.33	0.17	1.00	0.99	0.75
Transportation	1.00	0.59	0.97	0.16	1.00	-0.04	-0.06	1.00	0.97	0.86
Communication	0.99	0.97	0.99	0.00	0.97	0.81	0.50	1.00	0.95	0.84
						Value added				
Food	0.91	1.00	0.84	0.97	0.77	0.43	-0.58	1.00	0.96	0.49
Textiles	0.99	0.99	0.99	1.00	0.99	0.46	0.87	0.95	1.00	0.72
Publishing	1.00	1.00	0.99	0.96	0.95	0.45	0.94	1.00	1.00	0.93
Chemicals	0.97	0.99	0.99	0.99	0.95	0.45	1.00	0.88	0.99	0.81
Plastics	0.97	1.00	1.00	0.99	0.92	0.61	0.92	0.96	1.00	0.88
Metals	0.80	0.98	0.96	1.00	1.00	0.80	0.98	0.96	1.00	0.97
Electrical Eq	0.98	0.99	1.00	1.00	0.96	0.72	0.05	-0.05	0.99	0.88
Machinery	0.99	1.00	1.00	0.99	0.99	0.80	0.99	0.98	1.00	0.94
Transport Eq	1.00	1.00	0.65	0.98	0.98	0.65	0.96	0.64	0.97	0.89
Agriculture	0.79	0.96	0.99	0.75	0.98	-0.45	0.99	0.79	0.83	0.93
Mining	0.96	0.98	1.00	0.99	0.95	-0.37	0.90	0.74	1.00	0.83
Construction	1.00	1.00	0.99	1.00	1.00	0.08	0.93	0.98	1.00	0.95
Wholesale	1.00	1.00	1.00	0.94	0.86	0.66	0.99	1.00	1.00	0.93
Transportation	0.98	0.99	1.00	0.99	1.00	0.51	0.99	1.00	0.98	0.87
Communication	1.00	1.00	1.00	0.98	1.00	-0.14	1.00	0.99	1.00	0.93

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.

Notes: Bilateral correlations. Each cell shows the correlation between KLEMS 2019 and KLEMS 2012 series of employment, real capital, and real value-added growth. Canada is excluded as data is not available in KLEMS 2019.

Table A3. Data sources

Country	Data source
United States	KLEMS 2012 (1981-1995); KLEMS 2019 (1996-2015)
Japan	KLEMS 2012 (1981-2010); KLEMS 2019 (1996-2015)
Germany	KLEMS 2011 (1981-1989); KLEMS 2012 (1990-1995); KLEMS 2019 (1996-2015)
United Kingdom	KLEMS 2012 (1981-1995); KLEMS 2019 (1996-2015)
France	KLEMS 2012 (1981-1995); KLEMS 2019 (1996-2015)
Italy	KLEMS 2012 (1981-1995); KLEMS 2019 (1996-2015)
Canada	KLEMS 2012 (1981-2010); Statistics Canada Multifactor Productivity; Statistics Canada Employment
Austria	KLEMS 2012 (1981-1995); KLEMS 2019 (1996-2015)
Spain	KLEMS 2012 (1981-1995); KLEMS 2019 (1996-2015)
Netherlands	KLEMS 2011 (1981-1989); KLEMS 2012 (1990-1995); KLEMS 2019 (1996-2015)
Finland	KLEMS 2012 (1981-1995); KLEMS 2019 (1996-2015)
Belgium	KLEMS 2012 (1981-1995); KLEMS 2019 (1996-2015)
Denmark	KLEMS 2012 (1981-1995); KLEMS 2019 (1996-2015)

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: Each row details the data source used for each country for the years in brackets.

Table A4. Sector descriptions and codes across datasets

KLEMS 2017		KLEMS 2012	
Description	**Code**	**Description**	**Code**
AGRICULTURE, FORESTRY AND FISHING	A	AGRICULTURE, FORESTRY AND FISHING	AtB
MINING AND QUARRYING	B	MINING AND QUARRYING	C
Food products, beverages and tobacco	10-12	Food products, beverages and tobacco	15t16
Textiles, wearing apparel, leather and related prodcuts	13-15	Textiles, wearing apparel, leather and related prodcuts	17t19
Wood and paper products; printing and reproduction of recorded media	16-18	WOOD AND OF WOOD AND CORK	20
		PULP, PAPER, PAPER , PRINTING AND PUBLISHING	21t22
Coke and refined petroleum products	19	Coke, refined petroleum and nuclear fuel	23
Chemicals and chemical products	20-21	Chemicals and chemical	24
Rubber and plastics products, and other non-metallic mineral products	22-23	Rubber and plastics	25
		OTHER NON-METALLIC MINERAL	26
Basic metals and fabricated metal products, except machinery and equipment	24-25	BASIC METALS AND FABRICATED METAL	27t28
Electrical and optical equipment	26-27	ELECTRICAL AND OPTICAL EQUIPMENT	30t33
Machinery and equipment n.e.c.	28	MACHINERY, NEC	29
Transport equipment	29-30	TRANSPORT EQUIPMENT	34t35
Other manufacturing; repair and installation of machinery and equipment	31-33	MANUFACTURING NEC; RECYCLING	36t37
ELECTRICITY, GAS AND WATER SUPPLY	D-E	ELECTRICITY, GAS AND WATER SUPPLY	E
CONSTRUCTION	F	CONSTRUCTION	F
WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES AND MOTORCYCLES	G	WHOLESALE AND RETAIL TRADE	G
Wholesale and retail trade and repair of motor vehicles and motorcycles	45	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	50
Wholesale trade, except of motor vehicles and motorcycles	46	Wholesale trade and commission trade, except of motor vehicles and motorcycles	51
Retail trade, except of motor vehicles and motorcycles	47	Retail trade, except of motor vehicles and motorcycles; repair of household goods	52
Transport and storage	49-52	TRANSPORT AND STORAGE	60t63
ACCOMMODATION AND FOOD SERVICE ACTIVITIES	I	HOTELS AND RESTAURANTS	H
Postal and courier activities	53	POST AND TELECOMMUNICATIONS	64
Publishing, audiovisual and broadcasting activities	58-60		
Telecommunications	61		
IT and other information services	62-63		
FINANCIAL AND INSURANCE ACTIVITIES	K	FINANCIAL INTERMEDIATION	J
REAL ESTATE ACTIVITIES	L	Real estate activities	70
		Renting of m&eq and other business activities	71t74
PROFESSIONAL, SCIENTIFIC, TECHNICAL, ADMINISTRATIVE AND SUPPORT SERVICE ACTIVITIES	M-N		
COMMUNITY SOCIAL AND PERSONAL SERVICES	O-U		
Public administration and defence; compulsory social security	O	PUBLIC ADMIN AND DEFENCE; COMPULSORY SOCIAL SECURITY	L
Education	P	EDUCATION	M
Health and social work	Q	HEALTH AND SOCIAL WORK	N
Arts, entertainment and recreation	R		
Other service activities	S	OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES	O
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	T	PRIVATE HOUSEHOLDS WITH EMPLOYED PERSONS	P
Activities of extraterritorial organizations and bodies	U	EXTRA-TERRITORIAL ORGANIZATIONS AND BODIES	Q

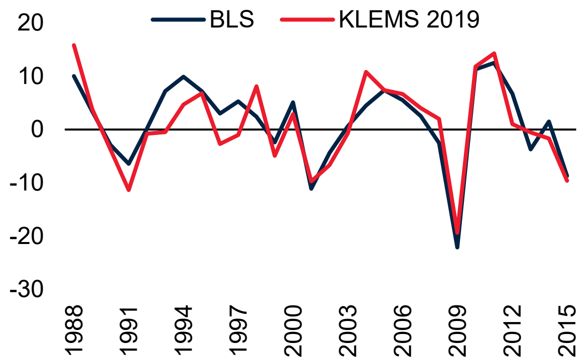
Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.

Notes: Each row details the sectoral matching across KLEMS 2012 and 2017 updates. Sector definition in KLEMS 2019 is similar to KLEMS 2017.

Figure A1. Sectoral data comparisons across sources – United States

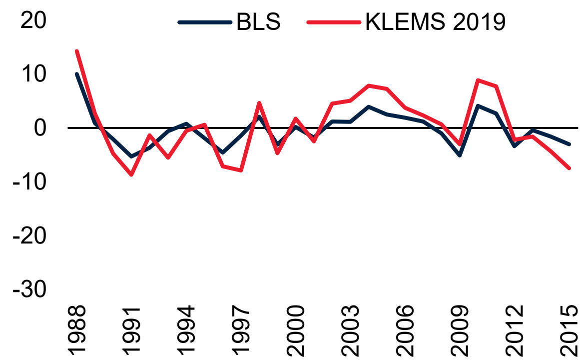
A. Output growth – Machinery

(*Percent*)



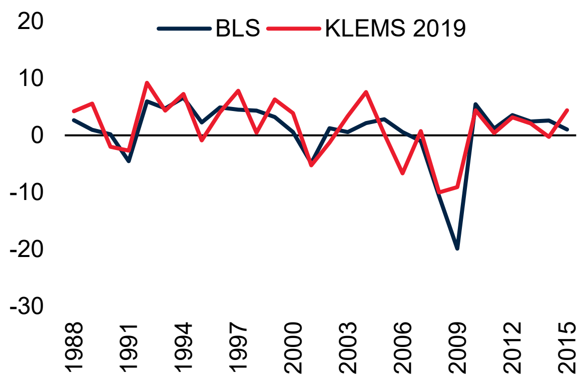
B. Productivity growth - Machinery

(*Percent*)



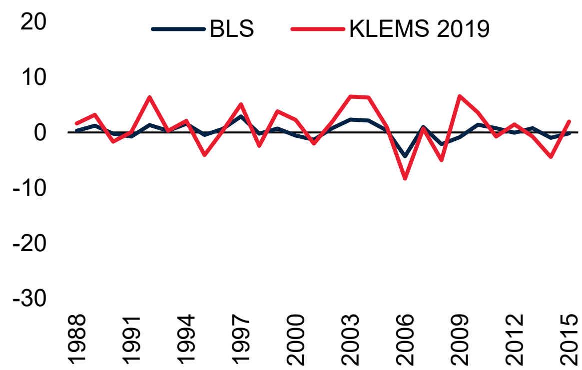
C. Output growth – Plastics

(*Percent*)



D. Productivity growth – Plastics

(*Percent*)



Sources: World KLEMS, Bureau of Labor Statistics.
Notes: In each panel, we graph the growth rates of the real variables. Plastics refers to "Rubber and plastics products, and other non-metallic mineral products". A and B. Blue lines show data for "Machinery" sector from Bureau of Labor Statistics (BLS). Red lines show data for "Machinery" sector from KLEMS 2019. C and D. Blues lines show data for the sum of sectors "Rubber and plastics" and "Other non-metallic mineral" from Bureau of Labor Statistics (BLS). Red lines show data for sector "Rubber and plastics products, and other non-metallic mineral products" from KLEMS 2019. Productivity refers to Total Factor Productivity (TFP).

Appendix B: Additional Tables and Figures

Table B1. Productivity growth – Basic statistics

	1981-2015			1981-1997			1998-2015		
	[1]	[2]	[3]	[1]	[2]	[3]	[1]	[2]	[3]
	Mean	**St. Dev.**	**Correl**	**Mean**	**St. Dev.**	**Correl**	**Mean**	**St. Dev.**	**Correl**
Average	1.20	5.82	0.13	1.45	5.65	0.11	0.96	5.97	0.16
United States	1.66	6.37	0.04	1.48	6.35	0.07	1.83	6.39	0.04
Japan	1.14	5.74	0.21	0.90	4.69	0.22	1.37	6.58	0.22
Germany	1.30	4.68	0.23	1.76	4.23	0.25	0.87	5.04	0.23
United Kingdom	0.80	4.12	0.20	0.99	3.43	0.21	0.63	4.68	0.21
France	0.83	4.35	0.17	1.41	4.25	0.16	0.29	4.38	0.17
Italy	0.94	4.62	0.19	1.33	4.66	0.15	0.57	4.55	0.26
Canada	0.92	5.65	0.11	1.02	5.67	0.05	0.83	5.63	0.17
Austria	1.18	5.12	0.06	1.51	5.64	0.04	0.86	4.57	0.10
Spain	1.42	5.36	0.14	1.27	4.58	0.06	1.56	6.02	0.20
Netherlands	1.97	6.65	0.12	2.22	4.64	0.14	1.73	8.10	0.12
Finland	1.54	5.33	0.05	1.80	5.37	0.02	1.30	5.29	0.09
Belgium	1.01	8.05	0.09	1.60	8.61	0.04	0.45	7.45	0.14
Denmark	0.86	7.92	0.10	1.51	8.57	0.04	0.25	7.20	0.17
Food	0.62	4.39	0.04	0.95	4.25	0.04	0.31	4.50	0.03
Textiles	0.64	4.61	0.16	0.90	3.67	0.06	0.40	5.35	0.21
Publishing	1.22	4.35	0.17	1.06	4.60	0.18	1.37	4.10	0.16
Chemicals	2.04	5.60	0.17	2.80	5.66	0.19	1.32	5.46	0.12
Plastics	1.40	4.52	0.23	1.75	4.63	0.16	1.07	4.40	0.30
Metals	1.49	5.22	0.20	1.71	5.07	0.13	1.28	5.36	0.25
Electrical Eq.	3.09	6.98	0.25	3.04	5.31	0.19	3.14	8.27	0.30
Machinery	1.35	6.02	0.29	1.22	5.41	0.18	1.48	6.56	0.38
Transport Eq.	1.84	8.09	0.16	1.57	8.73	0.07	2.09	7.45	0.24
Agriculture	1.39	7.64	0.06	1.94	7.55	0.08	0.87	7.70	0.03
Mining	0.25	10.02	0.04	2.09	9.83	-0.01	-1.48	9.92	0.05
Construction	0.07	3.52	0.16	0.43	3.57	0.18	-0.27	3.44	0.13
Wholesale	0.83	3.05	0.09	0.62	2.99	0.02	1.02	3.09	0.19
Transportation	0.71	3.99	0.26	1.51	3.80	0.19	-0.05	4.03	0.30
Communications	1.03	3.95	0.08	0.11	3.96	0.02	1.91	3.74	0.07

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: For each panel, columns [1] and [2] show the mean and standard deviation of productivity growth over time for each group. Each cell presents the unweighted average for the relevant cluster of countries or sectors. Column [3] presents the unweighted averages of bilateral correlations of all the series within the relevant cluster of countries or sectors. Global refers to all country-sector series. Productivity refers to capacity utilization-adjusted TFP.

Table B2. Output growth – Basic statistics

	1981-2015			1981-1997			1998-2015		
	[1]	[2]	[3]	[1]	[2]	[3]	[1]	[2]	[3]
	Mean	St. Dev.	Correl	Mean	St. Dev.	Correl	Mean	St. Dev.	Correl
Average	1.72	6.99	0.29	2.40	6.62	0.26	1.08	7.27	0.32
United States	2.51	7.48	0.23	3.22	7.36	0.24	1.84	7.54	0.25
Japan	1.29	7.78	0.31	3.01	7.21	0.20	-0.33	7.96	0.31
Germany	1.07	7.05	0.35	0.76	5.47	0.31	1.37	8.27	0.37
United Kingdom	1.07	5.35	0.33	1.91	4.88	0.40	0.28	5.66	0.30
France	1.26	4.82	0.29	1.47	4.12	0.37	1.05	5.40	0.26
Italy	1.25	5.21	0.39	2.26	4.24	0.27	0.29	5.84	0.43
Canada	1.87	6.61	0.51	2.52	6.64	0.55	1.27	6.53	0.53
Austria	1.81	6.39	0.23	1.67	5.97	0.12	1.95	6.76	0.32
Spain	1.85	6.27	0.30	2.85	6.49	0.16	0.91	5.91	0.41
Netherlands	2.02	6.05	0.23	2.42	5.05	0.16	1.65	6.85	0.28
Finland	2.38	8.93	0.30	2.89	7.35	0.44	1.89	10.18	0.27
Belgium	1.77	6.56	0.18	2.39	5.93	0.12	1.19	7.06	0.23
Denmark	2.20	10.30	0.15	3.87	11.53	0.09	0.61	8.71	0.20
Food	0.87	4.38	0.06	1.20	4.28	0.00	0.56	4.46	0.09
Textiles	-1.93	6.18	0.29	-0.95	5.25	0.06	-2.85	6.83	0.39
Publishing	0.80	5.39	0.36	2.02	4.89	0.26	-0.36	5.60	0.40
Chemicals	3.42	5.71	0.19	4.42	5.28	0.19	2.48	5.95	0.15
Plastics	1.39	6.09	0.47	2.42	5.46	0.26	0.41	6.49	0.60
Metals	1.40	6.83	0.50	1.78	5.66	0.34	1.04	7.76	0.59
Electrical Eq.	4.29	8.92	0.44	5.58	7.22	0.26	3.06	10.13	0.54
Machinery	1.81	8.20	0.56	1.83	7.47	0.37	1.79	8.84	0.71
Transport Eq.	1.92	9.41	0.37	2.32	8.91	0.15	1.55	9.87	0.52
Agriculture	1.53	7.59	0.08	2.02	7.58	0.05	1.06	7.58	0.10
Mining	0.28	11.18	0.02	1.78	11.94	-0.05	-1.13	10.22	0.06
Construction	0.50	5.19	0.20	0.69	5.56	0.21	0.33	4.82	0.20
Wholesale	2.40	3.73	0.27	2.92	3.93	0.16	1.91	3.47	0.38
Transportation	2.11	3.98	0.41	3.13	3.75	0.27	1.16	3.96	0.47
Communications	5.01	4.30	0.31	4.90	3.89	0.10	5.11	4.66	0.48

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: For each panel, columns [1] and [2] show the mean and standard deviation of output growth over time for each group. Each cell presents the GDP-weighted average for the relevant cluster of countries or sectors. Column [3] presents the unweighted averages of bilateral correlations of all the series within the relevant cluster of countries or sectors. Global refers to all country-sector series.

Table B3. Variance decompositions for sectoral productivity fluctuations by sector

(Percent, 1981-2015)

		33%	Global	66%	33%	Sectoral	66%	33%	Country	66%	33%	Idiosyncratic	66%
USA	Food	0.1	**0.3**	0.5	5.1	**7.6**	10.5	0.2	**0.5**	1.0	87.7	**90.8**	93.4
	Textiles	8.0	**9.6**	11.5	0.6	**1.5**	2.9	0.9	**1.8**	3.0	82.7	**85.2**	87.6
	Publishing	1.5	**2.2**	3.1	4.2	**7.4**	11.3	0.2	**0.5**	1.0	84.6	**88.7**	92.0
	Chemicals	2.6	**3.4**	4.3	0.5	**1.2**	2.3	3.6	**5.1**	6.9	86.2	**88.6**	90.7
	Plastics	0.1	**0.2**	0.4	2.6	**6.3**	12.1	17.3	**20.6**	24.2	64.4	**69.9**	74.4
	Metals	6.0	**7.4**	8.9	1.5	**2.5**	3.7	5.8	**7.9**	10.3	77.8	**81.0**	83.8
	Machinery	0.1	**0.3**	0.6	1.9	**4.5**	8.8	51.8	**57.4**	62.8	28.2	**34.0**	40.0
	Electrical Eq	1.5	**2.2**	3.1	1.7	**3.0**	4.8	8.6	**10.7**	13.1	79.5	**82.5**	85.1
	Transport Eq	1.3	**2.0**	2.7	26.4	**29.9**	33.7	0.2	**0.5**	1.1	63.0	**66.5**	70.0
	Wholesale	0.2	**0.5**	1.1	10.8	**14.7**	19.2	0.2	**0.5**	1.1	78.5	**83.2**	87.2
	Transportation	19.3	**21.7**	24.3	19.4	**25.5**	32.0	0.4	**0.9**	1.6	44.2	**50.7**	56.6
	Communications	0.5	**0.9**	1.5	6.6	**8.8**	11.5	39.9	**44.3**	48.7	40.0	**44.5**	49.1
	Agriculture	0.2	**0.5**	0.9	0.3	**0.7**	1.5	5.3	**7.3**	9.4	87.8	**90.3**	92.4
	Mining	4.6	**5.8**	7.0	0.5	**1.2**	2.4	30.0	**34.1**	38.3	52.9	**57.5**	61.6
	Construction	0.1	**0.2**	0.5	16.3	**19.6**	23.4	1.6	**2.8**	4.3	71.8	**76.1**	80.1
JPN	Food	1.2	**1.8**	2.6	7.7	**10.3**	13.2	2.6	**4.2**	6.3	78.3	**82.3**	85.8
	Textiles	9.9	**11.7**	13.6	1.3	**2.9**	5.3	1.4	**2.9**	5.2	76.4	**79.6**	82.4
	Publishing	4.1	**5.2**	6.4	3.9	**7.4**	12.1	2.1	**4.7**	8.4	73.7	**78.9**	83.4
	Chemicals	1.3	**2.0**	2.8	9.8	**13.1**	16.7	14.4	**20.2**	26.8	55.8	**63.3**	70.4
	Plastics	17.6	**19.8**	22.3	7.4	**12.1**	17.8	15.1	**19.6**	24.4	38.6	**44.9**	51.4
	Metals	0.7	**1.3**	2.2	0.3	**0.7**	1.4	6.2	**9.4**	13.4	82.6	**86.9**	90.5
	Machinery	11.0	**12.7**	14.4	13.6	**25.0**	34.6	12.6	**15.9**	19.3	34.1	**44.8**	56.3
	Electrical Eq	0.4	**0.9**	1.6	1.9	**3.5**	5.7	1.7	**3.4**	5.9	86.4	**89.8**	92.4
	Transport Eq	0.1	**0.2**	0.5	5.5	**7.8**	10.3	11.5	**15.3**	19.5	70.1	**75.3**	80.2
	Wholesale	0.2	**0.4**	0.8	9.6	**12.8**	16.3	13.0	**19.9**	27.9	56.9	**64.9**	72.0
	Transportation	0.1	**0.2**	0.3	0.4	**1.0**	2.1	0.9	**2.2**	4.2	92.6	**95.0**	96.9
	Communications	0.3	**0.7**	1.2	15.0	**19.7**	25.0	1.3	**3.1**	6.5	67.7	**72.5**	76.9
	Agriculture	0.1	**0.3**	0.6	16.9	**22.8**	29.7	6.2	**9.2**	12.9	58.0	**65.2**	72.0
	Mining	7.5	**9.3**	11.1	4.9	**7.4**	10.6	4.1	**6.0**	8.4	72.0	**75.0**	77.9
	Construction	0.6	**1.1**	1.7	0.3	**0.8**	1.6	0.5	**1.3**	2.5	93.7	**95.5**	96.8
GER	Food	3.2	**4.2**	5.3	24.9	**29.1**	33.5	1.7	**2.7**	4.2	58.4	**62.6**	67.0
	Textiles	0.1	**0.2**	0.3	0.9	**2.2**	4.5	0.4	**0.8**	1.6	93.0	**95.6**	97.3
	Publishing	13.7	**15.9**	18.2	1.0	**2.3**	4.7	2.7	**4.3**	6.2	71.5	**74.6**	77.3
	Chemicals	15.4	**17.5**	19.7	4.9	**6.9**	9.2	35.8	**40.0**	44.3	31.1	**34.5**	37.7
	Plastics	13.1	**15.1**	17.2	1.2	**2.7**	5.4	1.0	**1.9**	3.0	74.9	**77.8**	80.3
	Metals	17.4	**19.4**	21.4	0.3	**0.7**	1.4	18.8	**22.0**	25.3	53.8	**56.9**	59.7
	Machinery	21.7	**24.3**	27.0	0.8	**2.0**	3.6	39.4	**43.8**	48.0	25.1	**28.4**	31.8
	Electrical Eq	17.2	**19.3**	21.7	4.3	**6.5**	8.8	35.7	**40.0**	44.0	29.4	**33.2**	37.0
	Transport Eq	11.8	**13.4**	15.0	12.5	**14.9**	17.5	12.8	**15.2**	17.9	52.9	**55.4**	57.8
	Wholesale	16.3	**18.4**	20.5	7.6	**10.3**	13.1	27.0	**30.3**	33.6	37.1	**39.8**	42.5
	Transportation	5.6	**6.9**	8.4	20.6	**25.9**	32.1	6.8	**9.0**	11.5	50.5	**56.9**	62.3
	Communications	24.6	**26.8**	29.1	0.7	**1.5**	2.6	5.5	**7.4**	9.7	60.3	**62.8**	65.2
	Agriculture	1.9	**2.9**	4.0	9.7	**13.3**	17.4	2.9	**4.2**	5.8	74.2	**78.4**	81.9
	Mining	1.4	**2.2**	3.2	9.3	**12.7**	16.6	8.7	**11.3**	14.4	68.1	**72.3**	76.0
	Construction	0.1	**0.2**	0.5	37.9	**44.6**	51.3	0.3	**0.8**	1.6	46.6	**53.3**	60.0
UK	Food	2.4	**3.2**	4.2	18.8	**22.7**	27.1	0.3	**0.6**	1.2	67.8	**72.5**	76.7
	Textiles	1.7	**2.4**	3.3	1.0	**2.5**	5.0	0.2	**0.4**	0.9	90.5	**93.2**	95.1
	Publishing	19.5	**22.1**	24.7	0.5	**1.4**	2.8	3.4	**5.0**	7.0	66.6	**69.4**	72.0
	Chemicals	7.3	**8.7**	10.2	21.8	**26.6**	31.3	5.3	**6.9**	8.6	52.4	**57.3**	62.1
	Plastics	0.2	**0.5**	0.9	5.0	**9.2**	14.4	38.4	**43.2**	48.0	39.4	**44.3**	49.4
	Metals	0.1	**0.2**	0.4	5.9	**8.3**	11.6	21.6	**25.6**	29.8	58.7	**63.6**	68.5
	Machinery	9.2	**11.5**	13.8	1.3	**3.5**	8.0	49.6	**53.6**	57.6	22.9	**26.8**	30.6
	Electrical Eq	42.8	**46.7**	50.1	5.4	**8.0**	10.9	10.4	**13.1**	16.2	27.8	**31.1**	34.3
	Transport Eq	4.3	**5.6**	7.0	24.7	**29.4**	34.6	19.9	**23.2**	26.6	35.2	**40.2**	45.2
	Wholesale	30.8	**34.2**	37.7	15.1	**18.1**	21.5	7.1	**9.9**	13.1	32.6	**36.0**	39.7
	Transportation	30.6	**34.5**	38.3	2.8	**5.0**	8.2	0.3	**0.6**	1.2	54.0	**57.5**	60.8
	Communications	38.1	**41.6**	44.8	0.3	**0.7**	1.4	8.0	**10.4**	13.1	43.6	**45.9**	48.5
	Agriculture	4.1	**5.5**	7.1	0.6	**1.3**	2.4	14.2	**17.2**	20.2	71.9	**74.7**	77.4
	Mining	34.8	**37.7**	40.4	6.2	**8.5**	10.9	3.5	**4.8**	6.5	45.3	**47.9**	50.5
	Construction	5.1	**6.3**	7.7	0.7	**1.6**	3.1	0.3	**0.7**	1.3	87.5	**89.5**	91.3

Table B3. Variance decompositions for sectoral productivity fluctuations by sector … *continued*

(Percent, 1981-2015)

		33%	Global	66%	33%	Sectoral	66%	33%	Country	66%	33%	Idiosyncratic	66%
FRA	Food	0.1	**0.2**	0.3	41.5	**47.1**	52.9	0.3	**0.6**	1.3	45.5	**51.1**	56.8
	Textiles	6.9	**8.5**	10.3	11.9	**17.3**	23.2	0.2	**0.6**	1.3	66.7	**72.3**	77.6
	Publishing	1.5	**2.2**	3.0	15.4	**22.5**	31.2	0.2	**0.5**	1.1	65.0	**73.8**	80.9
	Chemicals	5.5	**6.8**	8.1	27.2	**32.0**	36.7	24.1	**28.0**	31.9	28.3	**32.6**	37.2
	Plastics	1.1	**1.9**	3.0	1.4	**3.3**	6.6	22.9	**27.2**	31.7	59.3	**64.4**	69.2
	Metals	0.4	**0.8**	1.6	58.6	**64.9**	70.5	0.3	**0.7**	1.4	26.7	**32.0**	38.2
	Machinery	19.2	**21.7**	24.2	2.0	**4.1**	6.9	33.8	**38.4**	42.9	29.5	**34.0**	38.3
	Electrical Eq	4.4	**5.7**	7.2	15.9	**20.5**	25.3	0.5	**1.2**	2.3	66.6	**71.1**	75.5
	Transport Eq	31.8	**34.5**	37.2	27.6	**30.7**	33.8	0.8	**1.6**	2.9	28.9	**32.0**	34.9
	Wholesale	18.7	**21.3**	24.1	11.1	**14.0**	16.9	26.3	**30.1**	34.0	30.3	**33.6**	36.6
	Transportation	27.4	**29.7**	32.3	0.3	**0.6**	1.3	2.3	**3.8**	5.6	61.4	**64.3**	66.9
	Communications	11.8	**13.7**	15.6	10.1	**12.6**	15.5	20.2	**24.0**	28.0	44.4	**48.5**	52.5
	Agriculture	15.0	**16.8**	18.8	2.3	**4.4**	7.0	14.9	**18.2**	21.6	54.5	**59.1**	63.2
	Mining	18.2	**20.6**	23.1	5.8	**8.1**	10.8	0.6	**1.3**	2.5	65.2	**67.8**	70.2
	Construction	18.9	**22.1**	25.3	25.7	**29.4**	33.2	6.8	**9.2**	12.0	33.8	**37.7**	41.7
ITA	Food	1.6	**2.2**	3.0	2.9	**5.0**	7.4	4.0	**5.5**	7.4	82.9	**86.1**	88.8
	Textiles	0.1	**0.3**	0.6	2.0	**4.1**	7.1	0.2	**0.6**	1.1	91.0	**94.0**	96.1
	Publishing	10.1	**11.9**	13.8	0.3	**0.8**	1.6	1.9	**3.0**	4.4	79.9	**82.9**	85.6
	Chemicals	20.4	**22.7**	25.2	10.7	**13.4**	16.3	17.7	**20.3**	23.0	39.6	**42.8**	46.1
	Plastics	16.7	**19.2**	21.7	0.8	**1.9**	3.7	18.6	**21.5**	24.6	51.9	**55.3**	58.7
	Metals	41.2	**44.2**	47.4	3.9	**5.9**	8.2	8.9	**11.2**	13.5	34.5	**37.4**	40.3
	Machinery	10.4	**12.1**	14.0	2.1	**4.1**	6.7	22.2	**25.2**	28.6	53.4	**56.9**	60.4
	Electrical Eq	10.6	**12.5**	14.7	1.8	**3.2**	4.9	44.5	**48.4**	52.1	31.3	**34.5**	37.6
	Transport Eq	7.2	**9.0**	10.9	0.2	**0.4**	0.8	40.5	**44.8**	49.0	41.3	**45.1**	48.7
	Wholesale	0.3	**0.7**	1.2	5.4	**7.6**	10.0	46.7	**50.6**	54.5	36.1	**40.0**	43.9
	Transportation	3.9	**5.4**	7.1	0.6	**1.3**	2.5	21.7	**24.9**	28.4	63.3	**66.6**	69.6
	Communications	3.6	**4.6**	5.8	32.5	**37.5**	42.6	0.2	**0.5**	1.0	51.2	**56.4**	61.6
	Agriculture	23.9	**26.7**	29.5	0.6	**1.4**	2.9	8.6	**10.7**	13.0	56.9	**59.4**	61.7
	Mining	1.7	**2.5**	3.4	30.7	**35.7**	41.4	7.3	**9.1**	11.2	46.7	**51.6**	56.1
	Construction	0.3	**0.7**	1.2	12.7	**16.4**	20.3	0.1	**0.3**	0.7	77.9	**81.8**	85.5
CAN	Food	10.1	**11.5**	13.1	0.2	**0.4**	0.8	0.6	**1.2**	2.1	84.2	**85.8**	87.4
	Textiles	31.0	**33.8**	36.7	7.9	**11.6**	15.8	7.9	**9.7**	11.7	39.4	**43.7**	47.7
	Publishing	2.7	**3.8**	5.0	0.8	**1.8**	3.6	7.7	**9.8**	12.1	79.8	**82.6**	85.0
	Chemicals	3.9	**5.2**	6.7	12.4	**16.1**	20.2	11.4	**13.6**	16.1	59.6	**63.9**	68.0
	Plastics	11.8	**14.0**	16.5	1.6	**3.8**	7.4	23.8	**26.9**	30.4	48.1	**52.1**	55.7
	Metals	14.6	**16.8**	19.1	3.4	**5.0**	7.2	31.5	**34.8**	38.2	38.5	**41.7**	44.7
	Machinery	7.2	**8.7**	10.3	1.8	**3.8**	6.5	52.7	**56.2**	59.5	26.1	**29.3**	32.4
	Electrical Eq	11.5	**13.9**	16.4	3.5	**5.5**	8.0	38.3	**41.8**	45.1	33.8	**37.3**	40.7
	Transport Eq	2.6	**3.6**	4.7	24.6	**27.7**	31.1	6.9	**8.6**	10.5	55.8	**59.0**	62.2
	Wholesale	0.7	**1.2**	1.8	6.2	**8.4**	11.1	17.1	**19.6**	22.2	66.2	**69.8**	73.1
	Transportation	11.5	**13.4**	15.6	5.1	**8.4**	12.3	7.6	**9.4**	11.3	63.6	**67.3**	70.5
	Communications	6.9	**8.4**	10.1	4.7	**6.9**	9.6	3.7	**5.1**	6.8	74.4	**78.2**	81.6
	Agriculture	21.2	**23.6**	26.0	0.4	**0.9**	1.9	7.4	**9.1**	11.0	62.3	**65.1**	67.9
	Mining	12.3	**14.0**	15.8	4.6	**6.6**	8.9	29.3	**32.6**	35.9	42.5	**45.7**	48.9
	Construction	0.1	**0.2**	0.3	6.2	**8.7**	11.8	24.8	**27.7**	30.7	58.1	**62.3**	66.4
AUT	Food	0.2	**0.4**	0.7	26.6	**31.1**	35.7	11.5	**14.3**	17.4	47.2	**53.0**	58.3
	Textiles	0.1	**0.3**	0.6	8.9	**15.9**	24.2	0.5	**1.1**	2.2	73.1	**81.2**	88.1
	Publishing	0.5	**0.9**	1.5	4.0	**7.2**	11.2	2.6	**4.3**	6.5	81.1	**85.3**	88.8
	Chemicals	18.6	**20.8**	23.2	0.3	**0.8**	1.9	7.2	**9.6**	12.3	61.6	**66.0**	70.0
	Plastics	2.5	**3.6**	4.8	0.6	**1.4**	2.8	2.3	**4.0**	6.3	86.2	**89.0**	91.3
	Metals	3.8	**5.0**	6.3	41.2	**46.4**	51.4	0.2	**0.5**	1.1	42.2	**47.0**	52.3
	Machinery	49.1	**52.4**	55.7	4.8	**8.3**	12.4	0.3	**0.7**	1.3	32.2	**36.3**	40.3
	Electrical Eq	24.4	**27.1**	30.0	12.8	**17.0**	21.1	15.2	**19.0**	23.0	30.6	**35.6**	40.8
	Transport Eq	11.6	**13.6**	15.8	1.2	**2.3**	3.6	9.0	**12.1**	16.0	66.8	**70.4**	73.5
	Wholesale	12.7	**14.7**	16.9	7.4	**9.7**	12.1	8.4	**10.9**	13.7	60.1	**63.7**	66.9
	Transportation	0.3	**0.7**	1.2	0.4	**0.9**	1.8	14.0	**17.4**	21.2	75.7	**79.6**	83.1
	Communications	0.4	**0.9**	1.5	7.9	**10.5**	13.4	34.0	**39.0**	44.0	42.6	**48.1**	53.5
	Agriculture	0.4	**0.9**	1.4	7.3	**10.6**	14.4	0.5	**1.1**	2.2	82.1	**85.8**	88.8
	Mining	12.8	**14.7**	16.6	0.5	**1.2**	2.3	2.3	**3.8**	5.8	75.9	**78.9**	81.3
	Construction	0.2	**0.6**	1.1	1.1	**2.2**	3.8	19.3	**23.1**	27.0	68.2	**72.5**	76.6

Table B3. Variance decompositions for sectoral productivity fluctuations by sector … *continued*

(Percent, 1981-2015)

		33%	Global	66%	33%	Sectoral	66%	33%	Country	66%	33%	Idiosyncratic	66%
ESP	Food	2.4	**3.4**	4.4	0.3	**0.7**	1.4	0.5	**1.0**	1.7	92.4	**93.8**	95.1
	Textiles	2.1	**3.1**	4.4	9.3	**13.8**	19.3	0.2	**0.4**	0.8	76.4	**81.6**	86.0
	Publishing	0.2	**0.4**	0.8	3.8	**7.5**	13.1	0.7	**1.4**	2.4	83.9	**89.5**	93.3
	Chemicals	2.3	**3.5**	4.9	23.7	**28.9**	34.3	3.7	**5.2**	6.8	55.6	**61.3**	66.8
	Plastics	23.6	**26.7**	30.0	5.5	**10.6**	17.1	20.6	**24.1**	27.8	30.9	**35.7**	40.3
	Metals	2.1	**3.3**	4.8	5.0	**6.9**	9.3	55.8	**60.6**	65.2	22.6	**27.3**	32.5
	Machinery	8.9	**10.7**	12.6	0.6	**1.5**	3.2	16.9	**19.9**	23.2	62.0	**66.0**	69.7
	Electrical Eq	3.4	**4.5**	5.7	31.7	**39.4**	46.4	0.3	**0.8**	1.6	47.1	**54.1**	61.7
	Transport Eq	0.6	**1.1**	1.7	6.1	**8.2**	10.8	19.3	**22.2**	25.5	62.9	**67.3**	71.4
	Wholesale	1.5	**2.5**	3.6	21.5	**25.7**	30.1	16.8	**19.6**	22.9	45.5	**50.6**	55.4
	Transportation	0.6	**1.2**	2.2	1.3	**3.1**	6.2	11.3	**13.9**	16.9	74.5	**78.9**	82.5
	Communications	15.4	**18.1**	20.9	13.8	**17.3**	21.2	0.4	**0.8**	1.5	58.0	**62.6**	67.1
	Agriculture	0.2	**0.4**	0.7	2.4	**4.4**	7.3	11.6	**13.8**	16.4	75.7	**79.6**	83.1
	Mining	19.2	**21.5**	23.8	8.4	**11.3**	14.5	0.6	**1.2**	2.0	62.0	**64.9**	67.5
	Construction	1.4	**2.1**	3.0	1.2	**2.5**	4.3	3.6	**5.1**	6.8	86.5	**88.8**	90.8
NLD	Food	0.1	**0.2**	0.4	10.1	**13.3**	17.0	1.2	**2.3**	3.8	79.1	**83.0**	86.3
	Textiles	0.1	**0.3**	0.6	2.5	**4.8**	7.7	3.7	**5.6**	7.9	84.1	**87.5**	90.5
	Publishing	0.1	**0.2**	0.4	0.5	**1.1**	2.4	0.2	**0.5**	1.0	95.8	**97.2**	98.2
	Chemicals	23.2	**25.3**	27.7	15.1	**18.3**	21.8	2.6	**4.2**	6.3	46.9	**50.5**	54.2
	Plastics	7.4	**9.4**	11.4	1.6	**3.9**	7.9	40.8	**47.4**	53.4	30.5	**35.3**	40.6
	Metals	2.1	**3.2**	4.5	3.9	**5.7**	7.9	0.9	**1.9**	3.4	84.3	**87.4**	90.1
	Machinery	7.0	**9.6**	12.1	6.0	**11.5**	17.7	39.2	**44.2**	49.0	26.3	**31.6**	37.1
	Electrical Eq	3.7	**4.9**	6.4	10.5	**14.8**	19.5	3.2	**5.3**	7.9	68.5	**73.6**	78.0
	Transport Eq	6.6	**7.9**	9.5	16.2	**19.4**	22.9	11.0	**13.7**	16.7	54.1	**57.5**	60.7
	Wholesale	49.5	**52.0**	54.5	9.0	**11.3**	13.7	2.6	**4.0**	5.7	29.0	**31.5**	34.1
	Transportation	22.9	**25.6**	28.4	1.0	**2.0**	3.6	7.8	**10.3**	13.5	57.2	**60.1**	62.7
	Communications	0.3	**0.6**	1.0	12.7	**16.7**	21.5	10.0	**13.0**	16.4	61.7	**68.5**	74.3
	Agriculture	31.9	**34.3**	36.9	0.4	**1.0**	2.1	9.9	**12.6**	15.7	47.6	**50.6**	53.3
	Mining	24.9	**27.6**	30.2	9.5	**12.2**	15.5	1.1	**2.1**	3.5	53.4	**56.3**	59.1
	Construction	0.3	**0.6**	1.2	22.5	**27.6**	33.6	1.3	**2.3**	3.7	62.4	**67.8**	73.1
FIN	Food	0.1	**0.2**	0.4	0.3	**0.8**	1.5	0.2	**0.6**	1.2	96.4	**97.6**	98.4
	Textiles	0.6	**1.2**	2.0	1.1	**2.7**	5.5	4.3	**6.5**	9.2	82.3	**86.4**	89.8
	Publishing	0.2	**0.4**	0.8	10.9	**17.0**	24.2	6.3	**9.3**	13.0	62.7	**70.6**	77.7
	Chemicals	18.8	**20.8**	22.8	0.2	**0.5**	1.2	16.8	**20.8**	25.2	51.2	**56.3**	60.6
	Plastics	42.6	**45.8**	49.3	1.7	**3.8**	7.4	0.2	**0.5**	1.0	42.8	**47.2**	51.4
	Metals	0.1	**0.2**	0.4	26.0	**30.5**	35.7	11.9	**16.2**	21.1	43.1	**50.6**	58.7
	Machinery	5.6	**8.0**	10.5	3.7	**7.9**	13.9	1.7	**3.4**	5.8	70.7	**77.1**	82.2
	Electrical Eq	22.5	**24.8**	27.2	0.2	**0.6**	1.3	3.6	**6.5**	10.1	62.0	**66.2**	70.2
	Transport Eq	7.9	**9.3**	10.9	2.0	**3.3**	4.8	0.6	**1.4**	2.4	82.6	**84.6**	86.5
	Wholesale	3.9	**5.0**	6.2	1.2	**2.1**	3.3	5.4	**8.6**	12.8	78.8	**82.6**	85.8
	Transportation	4.0	**5.1**	6.4	3.0	**5.2**	7.8	0.3	**0.7**	1.3	84.9	**87.5**	89.8
	Communications	5.0	**6.3**	7.7	0.7	**1.6**	3.0	0.4	**0.9**	1.9	87.0	**89.4**	91.4
	Agriculture	0.6	**1.3**	2.2	1.2	**2.7**	4.9	25.9	**31.1**	36.5	56.6	**62.4**	68.2
	Mining	22.5	**25.1**	27.8	26.8	**30.8**	34.9	8.0	**10.5**	13.2	28.6	**32.6**	36.7
	Construction	0.6	**1.1**	1.7	15.4	**18.9**	22.7	11.6	**15.3**	19.3	58.6	**63.2**	67.5
BEL	Food	0.6	**1.1**	1.7	15.4	**18.9**	22.7	11.6	**15.3**	19.3	58.6	**63.2**	67.5
	Textiles	0.9	**1.4**	2.1	1.4	**2.6**	4.1	0.4	**1.0**	1.9	91.6	**93.7**	95.4
	Publishing	5.1	**6.5**	8.0	3.2	**5.7**	9.1	0.3	**0.8**	1.6	81.9	**85.3**	87.9
	Chemicals	1.0	**2.0**	3.4	0.5	**1.3**	2.6	5.9	**9.7**	14.6	78.7	**84.6**	89.1
	Plastics	1.1	**1.9**	2.7	0.5	**1.1**	2.1	10.2	**15.9**	22.9	72.5	**79.4**	85.0
	Metals	1.2	**1.9**	2.8	1.1	**2.6**	5.5	26.0	**32.2**	38.8	52.1	**60.0**	66.9
	Machinery	10.3	**12.5**	15.0	1.5	**3.0**	5.2	0.2	**0.5**	1.0	78.8	**81.7**	84.6
	Electrical Eq	0.2	**0.5**	0.9	2.0	**4.6**	8.7	0.8	**1.9**	3.7	85.7	**89.9**	93.4
	Transport Eq	0.1	**0.3**	0.5	26.6	**34.8**	42.6	6.0	**8.5**	11.3	47.6	**55.8**	64.0
	Wholesale	16.6	**18.9**	21.3	47.6	**52.0**	56.6	3.4	**5.2**	7.5	17.5	**21.7**	26.1
	Transportation	7.8	**9.7**	11.9	8.5	**11.0**	13.8	1.7	**3.2**	5.1	70.2	**73.8**	77.1
	Communications	2.2	**3.1**	4.2	0.5	**1.2**	2.4	5.2	**10.2**	16.1	77.8	**83.4**	88.2
	Agriculture	0.1	**0.2**	0.4	0.2	**0.5**	1.1	9.6	**13.9**	19.2	79.3	**84.4**	88.8
	Mining	0.1	**0.4**	0.7	22.7	**28.1**	34.2	0.9	**2.0**	3.9	61.0	**67.6**	73.3
	Construction	1.2	**2.0**	3.1	19.8	**24.9**	30.4	1.9	**4.2**	7.8	59.4	**66.0**	71.8
DNK	Food	0.6	**1.1**	1.8	9.0	**12.5**	16.6	8.5	**12.6**	17.9	64.9	**70.2**	75.1
	Textiles	7.1	**8.9**	10.8	0.8	**1.7**	3.0	0.2	**0.6**	1.2	84.8	**87.3**	89.6
	Publishing	7.4	**8.8**	10.3	0.5	**1.3**	2.7	8.8	**11.7**	14.7	72.1	**76.2**	80.0
	Chemicals	0.1	**0.2**	0.4	5.3	**8.6**	12.7	0.4	**0.9**	1.8	84.7	**89.0**	92.4

Plastics	7.1	**8.8**	10.8	1.3	**2.6**	4.4	11.9	**15.7**	20.0	66.4	**71.0**	74.8
Metals	17.7	**19.8**	21.8	0.9	**2.3**	4.8	26.8	**31.6**	36.9	38.7	**43.8**	48.8
Machinery	3.5	**4.5**	5.5	0.2	**0.4**	0.9	5.4	**7.9**	10.8	83.5	**86.2**	88.6
Electrical Eq	21.9	**23.8**	25.9	0.3	**0.7**	1.4	10.3	**13.0**	15.9	58.2	**61.2**	64.0
Transport Eq	1.8	**2.5**	3.5	1.4	**2.6**	4.2	20.9	**25.8**	31.2	62.5	**67.8**	72.5
Wholesale	22.2	**25.2**	28.3	0.7	**1.4**	2.4	17.9	**22.1**	26.5	45.9	**50.1**	54.1
Transportation	4.0	**5.3**	6.7	25.3	**29.6**	34.5	16.2	**20.3**	24.6	37.5	**43.5**	49.1
Communications	1.4	**2.0**	2.8	18.5	**24.6**	31.4	0.2	**0.4**	0.9	65.5	**72.0**	78.0
Agriculture	0.1	**0.2**	0.4	27.9	**33.5**	40.4	0.7	**1.6**	3.0	55.8	**63.3**	69.6
Mining	6.8	**8.2**	9.9	12.2	**17.0**	22.6	3.9	**5.8**	8.3	60.5	**66.4**	72.1
Construction	10.1	**11.9**	13.7	15.5	**18.7**	22.5	0.7	**1.5**	2.7	62.9	**66.4**	69.7

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: Variance share of productivity growth attributable to the relevant factor estimated using a dynamic factor model of 11 countries and 15 sectors. The variance contributions are attributed to: Global (global factor), Sectoral (sector-specific factor), Country (country-specific factor), and Idiosyncratic (idiosyncratic factor). Productivity refers to capacity utilization-adjusted TFP. The numbers in bold correspond to the median of posterior shares. 33% and 66% correspond to the 33^{rd} and 66^{th} quintiles of posterior shares.

Table B4. Variance decompositions for sectoral output fluctuations by sector

(Percent, 1981-2015)

		33%	**Global**	66%	33%	**Sectoral**	66%	33%	**Country**	66%	33%	**Idiosyncratic**	66%
USA	Food	0.2	**0.3**	0.5	9.8	**12.3**	15.4	0.1	**0.2**	0.4	83.7	**86.8**	89.3
	Textiles	9.7	**11.0**	12.2	0.3	**0.8**	1.6	2.4	**3.3**	4.5	81.6	**83.7**	85.5
	Publishing	1.2	**1.7**	2.3	2.3	**4.5**	7.3	0.1	**0.3**	0.6	90.1	**92.9**	95.1
	Chemicals	18.1	**19.7**	21.2	0.4	**0.9**	1.7	19.2	**21.4**	23.6	55.0	**57.1**	59.3
	Plastics	7.8	**8.7**	9.7	18.8	**21.8**	24.8	31.8	**34.4**	37.0	32.0	**34.8**	37.4
	Metals	6.4	**7.4**	8.4	15.8	**18.6**	21.6	5.2	**6.5**	8.0	63.9	**67.0**	69.6
	Machinery	13.2	**14.6**	16.0	2.0	**3.1**	4.6	54.6	**57.4**	60.1	21.8	**24.1**	26.4
	Electrical Eq	30.0	**31.8**	33.8	1.2	**2.1**	3.3	25.8	**27.9**	30.3	35.2	**37.1**	38.9
	Transport Eq	10.5	**11.6**	13.0	33.0	**35.8**	38.7	6.0	**7.3**	8.7	42.0	**44.7**	47.3
	Wholesale	37.2	**39.2**	41.2	17.6	**20.3**	23.2	1.6	**2.3**	3.2	35.3	**37.7**	39.8
	Transportation	58.7	**60.4**	62.1	2.7	**3.6**	4.6	6.2	**7.5**	8.7	26.5	**28.0**	29.5
	Communications	14.1	**15.6**	17.1	5.6	**7.2**	8.9	46.4	**49.2**	52.1	24.4	**27.2**	30.2
	Agriculture	18.5	**20.0**	21.5	6.3	**8.6**	11.1	23.9	**26.2**	28.5	41.9	**44.4**	46.9
	Mining	18.6	**20.3**	22.0	3.3	**4.6**	6.1	44.6	**47.3**	50.0	24.8	**27.0**	29.2
	Construction	2.7	**3.3**	4.0	10.4	**12.0**	13.7	3.5	**4.5**	5.6	77.6	**79.7**	81.6
JPN	Food	2.3	**2.9**	3.4	9.1	**11.5**	14.1	0.9	**1.4**	2.2	80.7	**83.5**	86.2
	Textiles	20.4	**22.1**	23.9	1.7	**3.4**	5.8	0.2	**0.5**	0.9	70.1	**72.5**	74.7
	Publishing	9.4	**10.6**	11.8	1.4	**3.2**	5.7	9.6	**11.8**	14.2	69.7	**72.5**	75.1
	Chemicals	5.9	**6.7**	7.5	12.7	**15.4**	18.3	37.5	**40.5**	43.5	33.8	**36.8**	39.9
	Plastics	14.3	**15.7**	17.3	19.3	**22.3**	25.6	31.4	**34.3**	37.3	24.0	**26.7**	29.4
	Metals	1.3	**1.7**	2.3	25.7	**29.8**	34.0	25.5	**28.2**	31.0	35.3	**39.7**	43.8
	Machinery	57.7	**59.6**	61.3	1.8	**2.6**	3.7	11.9	**13.4**	15.0	22.4	**23.8**	25.2
	Electrical Eq	45.2	**47.0**	48.8	1.0	**1.7**	2.5	13.2	**15.0**	16.8	34.0	**35.7**	37.4
	Transport Eq	38.8	**40.5**	42.0	8.4	**9.8**	11.2	29.5	**31.7**	33.9	15.9	**17.6**	19.3
	Wholesale	45.2	**47.2**	49.0	16.1	**17.8**	19.6	20.2	**22.2**	24.3	10.9	**12.3**	13.8
	Transportation	28.7	**30.2**	31.8	0.4	**0.8**	1.4	14.5	**16.7**	19.0	49.4	**51.5**	53.4
	Communications	0.1	**0.2**	0.3	5.3	**7.2**	9.6	4.5	**6.0**	7.8	83.1	**85.5**	87.6
	Agriculture	0.8	**1.2**	1.7	17.8	**21.1**	24.7	22.7	**25.4**	28.1	47.8	**51.6**	55.2
	Mining	27.6	**29.4**	31.1	0.3	**0.6**	1.1	26.2	**28.8**	31.4	38.4	**40.6**	42.8
	Construction	0.1	**0.1**	0.3	14.3	**16.9**	19.7	0.1	**0.3**	0.6	79.5	**82.2**	84.8
GER	Food	0.5	**0.8**	1.1	26.0	**30.0**	33.9	0.2	**0.4**	0.8	64.3	**68.3**	72.1
	Textiles	0.1	**0.2**	0.4	6.5	**11.5**	17.0	13.2	**16.0**	19.0	64.6	**71.0**	76.8
	Publishing	10.9	**12.0**	13.2	3.3	**5.8**	8.8	1.3	**2.3**	3.5	75.9	**78.9**	81.3
	Chemicals	71.6	**73.4**	75.2	0.9	**1.3**	1.9	12.8	**14.5**	16.1	9.2	**10.3**	11.4
	Plastics	26.2	**28.0**	29.8	5.7	**7.5**	9.6	6.9	**8.6**	10.6	52.7	**54.9**	56.9
	Metals	58.2	**60.2**	62.2	1.3	**2.1**	3.2	1.9	**2.7**	3.8	32.4	**34.0**	35.5
	Machinery	62.2	**64.2**	66.2	7.3	**8.8**	10.4	12.2	**14.1**	16.0	10.9	**12.3**	13.8
	Electrical Eq	62.0	**64.0**	65.9	6.7	**8.0**	9.4	11.3	**13.0**	14.8	13.5	**14.6**	15.7
	Transport Eq	59.7	**61.4**	63.0	9.4	**10.7**	12.1	9.9	**11.6**	13.2	14.6	**16.0**	17.4
	Wholesale	65.0	**67.1**	69.1	12.5	**13.9**	15.4	8.4	**9.9**	11.4	7.8	**8.7**	9.5
	Transportation	47.3	**49.2**	51.0	26.4	**28.9**	31.4	7.0	**8.4**	10.0	10.8	**13.0**	15.3
	Communications	8.7	**9.9**	11.1	3.0	**4.3**	5.8	9.0	**11.4**	14.2	70.8	**73.3**	75.7
	Agriculture	3.8	**4.7**	5.7	19.7	**23.1**	26.7	25.0	**28.6**	32.4	38.5	**42.6**	46.6
	Mining	12.3	**13.6**	14.9	10.1	**12.5**	15.2	4.7	**6.3**	8.1	64.0	**66.9**	69.5
	Construction	1.2	**1.6**	2.2	37.5	**41.3**	45.3	5.4	**7.0**	9.0	44.8	**49.2**	53.3
UK	Food	2.1	**2.5**	3.0	23.7	**27.2**	31.4	0.3	**0.6**	1.0	64.9	**69.1**	72.8
	Textiles	0.4	**0.6**	1.0	6.0	**10.8**	16.1	0.7	**1.2**	1.9	81.4	**86.8**	91.4
	Publishing	19.5	**21.0**	22.4	2.6	**4.3**	6.6	4.0	**5.0**	6.2	66.4	**68.9**	71.0
	Chemicals	13.2	**14.5**	15.8	11.5	**14.0**	17.0	18.2	**20.2**	22.4	47.5	**50.6**	53.6
	Plastics	12.8	**14.2**	15.8	11.4	**13.5**	15.7	41.5	**44.2**	46.9	25.3	**27.4**	29.6
	Metals	0.1	**0.1**	0.3	9.0	**11.6**	14.5	20.1	**22.9**	25.7	61.0	**64.5**	67.9
	Machinery	27.0	**28.9**	30.9	2.5	**3.6**	5.0	53.2	**55.6**	57.9	9.8	**11.2**	12.6
	Electrical Eq	58.1	**59.9**	61.7	10.2	**11.9**	13.6	10.4	**11.9**	13.4	14.7	**15.9**	17.1
	Transport Eq	20.6	**22.2**	23.8	24.7	**27.3**	30.3	18.4	**20.4**	22.5	26.8	**29.6**	32.5
	Wholesale	58.8	**60.7**	62.5	8.3	**9.8**	11.5	3.6	**4.6**	5.6	23.1	**24.3**	25.7
	Transportation	50.1	**51.9**	53.6	4.3	**5.6**	7.2	1.2	**1.8**	2.5	38.3	**40.0**	41.8
	Communications	40.1	**41.8**	43.6	5.2	**6.4**	7.7	23.6	**25.7**	27.7	23.7	**25.5**	27.4
	Agriculture	11.5	**12.8**	14.2	0.3	**0.7**	1.3	47.7	**50.4**	53.0	33.2	**35.4**	37.7
	Mining	29.2	**31.0**	33.0	17.2	**20.2**	23.6	13.3	**15.2**	17.1	30.1	**32.9**	35.8
	Construction	11.9	**13.2**	14.5	25.6	**27.9**	30.3	1.5	**2.3**	3.1	53.7	**56.1**	58.5

Table B4. Variance decompositions for sectoral output fluctuations by sector … *continued*

(Percent, 1981-2015)

		33%	Global	66%	33%	Sectoral	66%	33%	Country	66%	33%	Idiosyncratic	66%
FRA	Food	0.1	**0.2**	0.4	51.2	**56.4**	61.5	0.2	**0.5**	1.0	37.4	**42.3**	47.3
	Textiles	5.6	**6.3**	7.1	0.5	**1.3**	2.9	0.2	**0.4**	0.9	88.9	**90.7**	92.0
	Publishing	5.6	**6.3**	7.0	18.9	**23.9**	29.5	1.0	**1.6**	2.4	61.7	**67.6**	72.8
	Chemicals	9.1	**10.3**	11.5	29.9	**33.3**	36.8	25.1	**28.2**	31.2	24.0	**27.5**	31.1
	Plastics	0.6	**1.0**	1.5	2.7	**4.4**	6.6	38.1	**41.7**	45.5	47.4	**51.5**	55.7
	Metals	0.2	**0.5**	0.8	0.6	**1.3**	2.5	11.7	**14.4**	17.3	79.7	**82.7**	85.6
	Machinery	19.0	**20.7**	22.3	0.7	**1.5**	2.6	48.8	**52.0**	55.2	22.2	**24.9**	27.7
	Electrical Eq	6.1	**7.0**	8.0	14.8	**18.1**	21.7	3.9	**5.3**	6.8	65.8	**69.0**	71.8
	Transport Eq	54.1	**55.8**	57.8	20.0	**22.0**	24.0	0.4	**0.9**	1.6	18.9	**20.6**	22.3
	Wholesale	37.6	**40.1**	42.5	10.3	**12.0**	13.7	31.0	**33.8**	36.4	12.4	**13.8**	15.2
	Transportation	39.2	**41.0**	42.9	10.0	**12.2**	14.5	10.0	**11.9**	13.8	32.1	**34.2**	36.3
	Communications	5.2	**6.2**	7.3	22.3	**25.5**	29.1	20.1	**22.9**	26.0	41.7	**44.6**	47.1
	Agriculture	12.4	**13.9**	15.6	7.8	**10.5**	13.6	37.3	**40.5**	43.6	31.6	**33.9**	36.4
	Mining	32.2	**34.0**	35.9	15.3	**18.1**	21.0	8.9	**10.9**	13.1	33.7	**36.0**	38.3
	Construction	17.9	**19.7**	21.5	6.5	**8.1**	10.0	30.7	**34.0**	37.2	35.0	**37.3**	39.6
ITA	Food	0.4	**0.6**	0.9	1.0	**1.9**	3.1	0.8	**1.6**	2.6	93.4	**95.0**	96.2
	Textiles	1.3	**1.8**	2.3	0.5	**1.3**	2.8	0.3	**0.6**	1.3	93.4	**95.1**	96.3
	Publishing	10.7	**12.0**	13.4	2.9	**5.0**	7.6	0.6	**1.2**	2.2	77.7	**80.5**	82.7
	Chemicals	54.4	**56.6**	58.7	11.9	**13.6**	15.3	11.4	**13.2**	15.1	14.4	**16.2**	17.9
	Plastics	39.3	**41.6**	43.8	1.1	**2.0**	3.1	16.9	**19.5**	22.2	34.3	**36.0**	37.7
	Metals	35.8	**37.9**	39.8	23.6	**26.9**	30.4	7.8	**9.6**	11.4	22.2	**25.4**	28.4
	Machinery	45.3	**47.4**	49.4	3.2	**4.5**	5.9	21.0	**23.5**	26.1	22.7	**24.1**	25.5
	Electrical Eq	54.3	**56.5**	58.7	7.4	**8.8**	10.2	20.9	**23.3**	25.8	9.8	**11.0**	12.2
	Transport Eq	47.2	**49.3**	51.5	4.7	**5.9**	7.2	24.4	**27.2**	29.8	15.6	**17.3**	18.9
	Wholesale	53.1	**55.2**	57.3	11.6	**13.0**	14.6	11.5	**13.5**	15.7	16.5	**17.8**	19.0
	Transportation	39.9	**41.9**	43.8	0.7	**1.3**	2.1	12.6	**14.7**	16.9	39.7	**41.4**	43.0
	Communications	2.2	**3.0**	3.9	46.7	**51.6**	56.3	4.2	**6.2**	8.6	33.9	**37.8**	42.2
	Agriculture	41.8	**44.1**	46.4	4.7	**6.2**	8.0	22.5	**25.1**	28.0	21.9	**23.7**	25.4
	Mining	11.1	**12.6**	14.2	27.4	**31.1**	34.6	15.6	**18.5**	21.7	33.6	**37.0**	40.3
	Construction	1.0	**1.4**	1.9	48.4	**51.4**	54.4	0.9	**1.7**	2.8	41.6	**44.6**	47.5
CAN	Food	17.5	**19.0**	20.5	0.1	**0.3**	0.5	4.6	**5.5**	6.5	73.3	**74.7**	76.2
	Textiles	47.5	**49.9**	52.1	5.3	**8.4**	11.3	8.1	**9.3**	10.7	29.0	**32.1**	35.0
	Publishing	3.3	**4.0**	4.9	0.5	**1.2**	2.4	25.5	**27.2**	28.9	64.6	**66.5**	68.4
	Chemicals	4.1	**5.0**	5.9	6.6	**8.4**	10.4	44.8	**47.1**	49.4	36.4	**38.9**	41.3
	Plastics	27.9	**29.6**	31.4	5.9	**7.2**	8.7	38.2	**40.5**	42.6	20.7	**22.2**	23.7
	Metals	11.8	**13.0**	14.4	18.9	**21.3**	23.6	36.3	**38.5**	40.8	24.7	**26.8**	28.9
	Machinery	25.8	**27.6**	29.4	0.1	**0.3**	0.5	58.4	**60.6**	62.7	10.0	**11.1**	12.3
	Electrical Eq	45.9	**48.1**	50.3	2.0	**2.7**	3.4	38.4	**40.4**	42.4	7.7	**8.5**	9.4
	Transport Eq	12.8	**14.2**	15.6	30.7	**32.9**	35.1	30.7	**32.7**	34.7	17.9	**19.9**	21.8
	Wholesale	14.5	**16.0**	17.6	15.7	**17.4**	19.1	43.5	**45.6**	47.7	19.0	**20.7**	22.4
	Transportation	27.4	**29.2**	31.0	0.4	**0.8**	1.4	30.0	**31.8**	33.7	36.4	**37.7**	39.1
	Communications	22.9	**24.7**	26.5	2.3	**3.3**	4.5	0.8	**1.2**	1.7	68.1	**70.1**	72.0
	Agriculture	33.9	**35.7**	37.7	0.5	**1.1**	1.7	30.2	**32.1**	34.1	29.1	**30.4**	31.8
	Mining	17.2	**18.6**	20.2	0.2	**0.5**	0.9	50.1	**52.2**	54.3	26.6	**28.1**	29.6
	Construction	9.6	**10.8**	12.1	32.7	**35.4**	38.2	15.1	**16.7**	18.4	34.2	**36.7**	39.2
AUT	Food	2.9	**3.6**	4.4	25.9	**30.1**	34.6	12.9	**15.7**	18.8	44.5	**49.4**	54.3
	Textiles	4.2	**5.0**	5.8	18.1	**28.6**	38.5	2.1	**3.9**	6.0	51.8	**61.0**	70.9
	Publishing	2.7	**3.3**	3.9	4.2	**6.8**	10.1	3.1	**5.0**	7.7	79.0	**82.6**	86.0
	Chemicals	36.5	**38.2**	39.9	0.2	**0.5**	1.0	2.0	**3.1**	4.5	55.0	**57.2**	59.4
	Plastics	20.4	**22.0**	23.7	0.3	**0.6**	1.2	4.9	**7.2**	9.7	66.7	**69.1**	71.4
	Metals	4.4	**5.2**	6.1	1.2	**2.4**	3.9	0.5	**1.2**	2.3	87.7	**90.0**	91.9
	Machinery	68.6	**70.6**	72.6	0.7	**1.4**	2.4	3.3	**4.5**	5.9	20.7	**22.4**	24.1
	Electrical Eq	44.9	**46.9**	49.0	17.4	**19.9**	22.7	8.3	**10.2**	12.1	20.0	**22.2**	24.3
	Transport Eq	10.1	**11.2**	12.4	4.0	**5.4**	7.0	6.5	**8.7**	11.3	71.1	**74.0**	76.4
	Wholesale	21.1	**23.0**	25.0	13.1	**15.6**	18.1	8.8	**11.3**	14.0	46.8	**49.4**	51.8
	Transportation	14.7	**16.2**	17.7	3.6	**5.1**	6.9	19.3	**22.8**	26.4	51.3	**54.9**	58.3
	Communications	2.7	**3.3**	3.9	2.3	**3.6**	5.1	32.7	**37.3**	41.8	50.6	**55.0**	59.3
	Agriculture	2.0	**2.6**	3.3	26.6	**31.6**	37.2	6.1	**8.7**	11.7	50.9	**55.5**	59.9
	Mining	15.1	**16.4**	17.6	2.6	**4.0**	5.8	13.3	**16.6**	20.3	58.1	**61.7**	65.0
	Construction	0.9	**1.3**	1.7	7.8	**9.7**	12.0	29.2	**34.1**	39.2	49.0	**54.0**	58.8

Table B4. Variance decompositions for sectoral output fluctuations by sector … *continued*

(Percent, 1981-2015)

		33%	Global	66%	33%	Sectoral	66%	33%	Country	66%	33%	Idiosyncratic	66%
ESP	Food	6.7	**7.8**	8.8	0.1	**0.3**	0.7	5.3	**6.9**	8.6	82.5	**84.4**	86.2
	Textiles	4.5	**5.4**	6.3	4.6	**8.4**	13.6	0.4	**0.9**	1.6	79.4	**84.2**	87.8
	Publishing	1.0	**1.3**	1.7	8.1	**12.4**	17.7	6.9	**8.8**	10.9	70.6	**76.2**	80.8
	Chemicals	19.2	**20.7**	22.3	22.2	**25.9**	29.8	12.5	**14.5**	16.5	34.3	**38.3**	41.9
	Plastics	20.6	**22.1**	23.6	21.0	**24.4**	28.0	34.8	**38.0**	40.9	12.7	**14.9**	17.2
	Metals	6.9	**7.9**	9.0	0.3	**0.6**	1.3	56.4	**59.8**	63.2	27.6	**30.8**	34.0
	Machinery	10.7	**12.2**	13.7	24.8	**29.0**	33.5	31.5	**34.5**	37.7	20.3	**23.5**	26.7
	Electrical Eq	27.4	**29.2**	31.1	26.2	**29.6**	33.1	12.6	**14.7**	17.0	22.7	**25.8**	29.0
	Transport Eq	8.1	**9.0**	10.0	5.4	**6.9**	8.5	23.2	**25.6**	28.1	55.5	**58.0**	60.4
	Wholesale	13.9	**15.4**	17.0	36.9	**40.2**	43.6	17.7	**20.1**	22.4	21.2	**23.9**	26.7
	Transportation	5.8	**6.7**	7.6	13.7	**16.4**	19.4	9.3	**11.5**	13.9	61.3	**64.6**	67.9
	Communications	0.1	**0.1**	0.3	47.0	**51.7**	56.4	19.3	**22.1**	25.3	21.7	**25.1**	28.6
	Agriculture	7.8	**8.9**	10.0	2.4	**4.1**	6.5	8.2	**10.2**	12.4	73.0	**75.2**	77.3
	Mining	22.5	**24.1**	25.8	7.9	**10.5**	13.5	3.3	**4.5**	5.7	57.4	**59.8**	62.3
	Construction	3.3	**3.9**	4.7	0.1	**0.3**	0.6	20.6	**23.3**	26.2	69.0	**72.1**	74.9
NLD	Food	0.3	**0.4**	0.7	16.4	**20.1**	24.0	0.7	**1.3**	2.3	73.5	**77.3**	80.9
	Textiles	4.4	**5.2**	5.9	2.4	**4.6**	7.3	1.9	**2.9**	4.1	83.6	**86.2**	88.5
	Publishing	2.4	**3.0**	3.6	1.5	**3.1**	5.5	0.1	**0.3**	0.7	90.4	**92.8**	94.5
	Chemicals	27.3	**28.9**	30.4	21.4	**24.4**	27.4	9.2	**10.9**	12.8	32.3	**35.2**	38.2
	Plastics	7.2	**8.2**	9.3	28.9	**33.0**	37.1	31.7	**35.3**	39.0	19.2	**22.3**	25.8
	Metals	6.0	**6.9**	7.9	6.8	**9.4**	12.1	1.4	**2.4**	3.7	77.3	**80.2**	82.8
	Machinery	17.6	**19.3**	20.9	13.6	**17.1**	21.0	28.9	**32.1**	35.3	27.5	**30.6**	33.7
	Electrical Eq	47.3	**49.6**	51.8	4.7	**6.4**	8.3	7.5	**9.0**	10.5	32.5	**34.2**	35.9
	Transport Eq	17.9	**19.4**	21.0	15.2	**17.4**	19.7	8.4	**10.2**	12.2	50.3	**52.3**	54.2
	Wholesale	66.7	**68.3**	69.8	0.1	**0.4**	0.7	0.9	**1.5**	2.2	27.8	**29.4**	30.8
	Transportation	21.5	**23.1**	24.8	29.9	**33.7**	37.7	4.6	**6.1**	7.7	32.7	**36.4**	40.1
	Communications	0.4	**0.7**	1.0	19.5	**22.7**	26.3	46.4	**50.5**	55.0	21.4	**24.8**	28.4
	Agriculture	36.2	**38.3**	40.3	18.6	**21.2**	23.9	22.2	**24.6**	27.1	13.3	**15.3**	17.4
	Mining	45.2	**47.4**	49.2	16.7	**19.2**	21.6	3.0	**4.0**	5.2	27.2	**29.1**	31.1
	Construction	2.7	**3.5**	4.3	53.3	**56.7**	60.0	3.9	**5.5**	7.4	30.6	**33.5**	36.4
FIN	Food	0.0	**0.1**	0.2	0.1	**0.3**	0.7	1.8	**2.6**	3.5	95.5	**96.5**	97.4
	Textiles	0.1	**0.1**	0.3	0.7	**1.8**	3.9	10.9	**12.8**	14.8	80.4	**83.6**	86.2
	Publishing	0.2	**0.3**	0.6	9.6	**13.9**	18.8	13.9	**16.3**	18.8	62.8	**68.4**	73.4
	Chemicals	10.7	**11.8**	12.9	0.1	**0.3**	0.5	49.6	**52.4**	55.3	32.3	**35.2**	37.9
	Plastics	60.5	**62.3**	64.1	0.3	**0.7**	1.2	1.7	**2.4**	3.2	32.3	**34.0**	35.7
	Metals	2.8	**3.4**	4.1	1.7	**2.9**	4.5	7.4	**8.9**	10.5	82.0	**83.8**	85.5
	Machinery	46.7	**48.8**	50.8	3.0	**4.1**	5.5	30.1	**32.4**	34.8	12.3	**13.9**	15.6
	Electrical Eq	41.4	**43.5**	45.5	2.5	**3.5**	4.8	13.2	**15.0**	17.0	35.5	**37.2**	38.9
	Transport Eq	12.6	**13.9**	15.2	15.6	**17.9**	20.4	4.5	**5.7**	7.0	59.7	**61.9**	64.2
	Wholesale	17.6	**19.0**	20.6	10.1	**11.9**	13.8	48.2	**51.0**	53.8	15.5	**17.6**	19.8
	Transportation	7.9	**8.9**	10.0	16.7	**19.6**	22.8	18.1	**20.4**	22.8	47.3	**50.5**	53.5
	Communications	24.7	**26.5**	28.3	6.0	**7.7**	9.8	0.6	**1.1**	1.8	61.3	**63.8**	66.1
	Agriculture	20.1	**21.8**	23.5	0.2	**0.5**	1.0	31.1	**34.3**	37.5	40.1	**42.8**	45.5
	Mining	40.8	**42.7**	44.6	11.3	**13.3**	15.4	12.1	**13.8**	15.6	27.7	**29.7**	31.6
	Construction	10.9	**12.2**	13.5	42.1	**45.3**	48.4	11.6	**13.6**	15.7	25.7	**28.4**	31.0
BEL	Food	2.7	**3.3**	3.9	3.5	**5.1**	7.0	0.1	**0.3**	0.7	88.6	**90.6**	92.4
	Textiles	10.4	**11.5**	12.6	3.3	**5.9**	9.5	0.3	**0.7**	1.2	77.4	**80.9**	83.5
	Publishing	0.1	**0.2**	0.4	0.6	**1.5**	2.7	39.8	**44.9**	50.0	46.8	**52.1**	57.4
	Chemicals	18.1	**19.8**	21.5	0.2	**0.6**	1.2	0.4	**0.9**	1.7	75.6	**77.6**	79.4
	Plastics	14.8	**16.1**	17.5	11.4	**14.7**	18.4	26.3	**30.5**	34.8	32.5	**37.2**	42.0
	Metals	2.9	**3.6**	4.3	39.4	**44.0**	48.8	5.1	**7.0**	9.1	40.1	**44.6**	48.8
	Machinery	8.3	**9.4**	10.7	27.5	**32.3**	37.0	24.2	**28.0**	32.0	24.2	**28.9**	33.8
	Electrical Eq	26.7	**28.4**	30.1	27.6	**31.2**	34.7	0.5	**1.1**	2.0	35.4	**38.6**	41.6
	Transport Eq	37.2	**39.2**	41.2	27.8	**30.2**	32.7	0.2	**0.4**	0.8	27.7	**29.6**	31.6
	Wholesale	49.7	**51.7**	53.7	15.1	**17.1**	19.4	3.8	**5.1**	6.5	23.9	**25.3**	26.8
	Transportation	30.3	**32.3**	34.2	2.1	**3.2**	4.6	2.3	**3.7**	5.4	57.3	**59.5**	61.7
	Communications	4.9	**5.9**	6.8	3.4	**5.0**	7.0	17.4	**20.6**	23.6	64.5	**67.4**	70.3
	Agriculture	1.2	**1.6**	2.1	0.4	**1.0**	2.0	8.9	**11.5**	14.6	81.7	**84.6**	87.4
	Mining	6.4	**7.5**	8.6	13.9	**17.1**	20.5	10.1	**13.0**	16.4	57.0	**61.0**	64.8
	Construction	0.2	**0.4**	0.6	30.5	**33.5**	36.5	9.5	**12.3**	15.4	49.4	**52.8**	56.1
DNK	Food	12.8	**14.0**	15.3	0.2	**0.5**	0.9	0.3	**0.8**	1.4	82.3	**83.9**	85.4
	Textiles	0.1	**0.1**	0.3	2.5	**5.3**	9.2	0.3	**0.6**	1.3	89.1	**92.9**	95.7
	Publishing	0.3	**0.6**	0.9	4.1	**7.3**	11.1	0.2	**0.4**	0.8	87.2	**91.2**	94.2
	Chemicals	5.2	**6.0**	6.8	17.7	**21.1**	24.7	19.8	**22.8**	26.0	44.8	**49.4**	53.6

Plastics	19.4	**20.9**	22.4	0.9	**1.7**	2.7	42.2	**45.6**	48.9	27.7	**30.8**	34.1
Metals	0.9	**1.2**	1.6	0.2	**0.4**	0.8	0.2	**0.6**	1.1	96.3	**97.0**	97.7
Machinery	20.4	**22.0**	23.5	2.1	**3.6**	5.4	30.3	**33.3**	36.5	37.1	**39.9**	42.8
Electrical Eq	6.1	**7.0**	8.0	4.1	**5.6**	7.4	28.8	**32.3**	36.1	50.5	**54.2**	57.8
Transport Eq	27.1	**28.6**	30.2	0.1	**0.2**	0.4	26.5	**29.3**	32.3	38.5	**41.3**	44.2
Wholesale	18.8	**20.4**	21.9	22.1	**24.5**	27.2	14.6	**17.0**	19.7	34.4	**37.5**	40.5
Transportation	1.1	**1.5**	2.0	10.9	**13.3**	16.0	1.2	**1.9**	2.9	79.9	**82.4**	84.8
Communications	1.1	**1.5**	2.0	2.9	**4.5**	6.4	24.8	**28.2**	31.6	60.7	**64.7**	68.8
Agriculture	8.7	**9.6**	10.6	6.6	**8.8**	11.5	1.7	**2.7**	3.9	75.3	**77.9**	80.3
Mining	15.5	**16.9**	18.4	11.0	**13.4**	16.1	1.6	**2.5**	3.5	63.8	**66.4**	68.8
Construction	0.7	**1.0**	1.4	13.4	**15.3**	17.5	1.9	**2.9**	4.0	77.7	**80.1**	82.3

Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: Variance share of output growth attributable to the relevant factor estimated using a dynamic factor model of 13 countries and 15 sectors. The variance contributions are attributed to: Global (global factor), Sectoral (sector-specific factor), Country (country-specific factor), and Idiosyncratic (idiosyncratic factor). The numbers in bold correspond to the median of posterior shares. 33% and 66% correspond to the 33rd and 66th quintiles of posterior shares.

Appendix C: Details of the General Equilibrium IRBC Model

Equilibrium. The equilibrium conditions of the model are given as follows.

$$1 = \beta E_t \left[\left(\frac{C_{it}}{C_{it+1}} \right) \left(\frac{r_{it+1}}{p^f_{it+1}} + (1-\delta) \right) \right] \tag{C1}$$

$$\chi L_{it}^{1/\varepsilon} = \left(\frac{1}{C_{it}} \right) \frac{w_{it}}{p^f_{it}} \tag{C2}$$

$$\frac{p^f_{it} C_{it}}{p^f_{it+1} C_{it+1}} = \frac{p^f_{1t} C_{1t}}{p^f_{1t+1} C_{1t+1}} \tag{C3}$$

$$p^f_{it}(s) F_{it}(s) = \gamma_i(s) p^f_{it} F_{it} \tag{C4}$$

$$F_{jit}(s) = \omega^f_{ji}(s) \left(\frac{p_{jt}(s)}{p^f_{it}(s)} \right)^{1/(\rho-1)} F_{it}(s) \tag{C5}$$

$$V_{it}(s) = Z_{it}(s)^{\sigma/(1-\sigma)} \theta_i(s) \left(\frac{p^v_{it}(s)}{p_{it}(s)} \right)^{1/(\sigma-1)} Q_{it}(s) \tag{C6}$$

$$X_{it}(s) = Z_{it}(s)^{\sigma/(1-\sigma)} \big(1-\theta_i(s)\big) \left(\frac{p^x_{it}(s)}{p_{it}(s)} \right)^{1/(\sigma-1)} Q_{it}(s) \tag{C7}$$

$$r_{it} K_{it}(s) = \alpha p^v_{it}(s) V_{it}(s) \tag{C8}$$

$$w_{it} L_{it}(s) = (1-\alpha) p^v_{it}(s) V_{it}(s) \tag{C9}$$

$$X_{jit}(s', s) = \omega^x_{jt}(s', s) \left(\frac{p_{jt}(s')}{p^x_{it}(s)} \right)^{1/(\eta-1)} X_{it}(s) \tag{C10}$$

The market clearing conditions are given by the following equations:

$$Q_{it}(s) = \sum_{j=1}^{N} \sum_{s'=1}^{S} F_{ijt}(s) + X_{ijt}(s, s') \tag{C11}$$

$$F_{it} = C_{it} + K_{it+1} - (1-\delta) K_{it} \tag{C12}$$

$$K_{it} = \sum_{s=1}^{S} K_{it}(s) \tag{C13}$$

$$L_{it} = \sum_{s=1}^{S} L_{it}(s) \tag{C14}$$

Production functions and composite aggregators are given by the following equations:

$$Q_{it}(s) = Z_{it}(s) \left(\theta_i(s)^{1-\sigma} V_{it}(s)^{\sigma} + \big(1-\theta_i(s)\big)^{1-\sigma} X_{it}(s)^{\sigma} \right)^{1/\sigma} \tag{C15}$$

$$X_{it}(s) = \left(\sum_j \sum_{s'} \ \omega_{ji}^x(s', s)^{1-\eta} X_{jit}(s', s)^{\eta}\right)^{1/\eta} \tag{C16}$$

$$V_{it}(s) = K_{it}(s)^{\alpha} L_{it}(s)^{1-\alpha} \tag{C17}$$

$$F_{it}(s) = \left(\sum_j \ \omega_{ji}^f(s)^{1-\rho} F_{jit}(s)^{\rho}\right)^{1/\rho} \tag{C18}$$

$$F_{it} = \prod_s \ F_{it}(s)^{\gamma_i(s)} \tag{C19}$$

Linearization. The log-linearized version of the model is given as follows.

$$0 = E_t\left[\hat{C}_{it} - \hat{C}_{it+1} + \left(1 - \beta(1-\delta)\right)\left(\hat{r}_{it+1} - \hat{p}_{it+1}^f\right)\right] \tag{C20}$$

$$0 = \frac{1}{\varepsilon}\hat{L}_{it} + \hat{C}_{it} - \widehat{w}_{it} + \hat{p}_{it}^f \tag{C21}$$

$$\hat{p}_{it}^f + \hat{C}_{it} - \hat{p}_{it+1}^f - \hat{C}_{it+1} = \hat{p}_{1t}^f + \hat{C}_{1t} - \hat{p}_{1t+1}^f - \hat{C}_{1t+1} \tag{C22}$$

$$\hat{p}_{it}^f(s) + \widehat{F}_{it}(s) = \hat{p}_{it}^f + \widehat{F}_{it} \tag{C23}$$

$$\widehat{F}_{jit}(s) = \frac{\hat{p}_{jt}(s)}{\rho-1} - \frac{\hat{p}_{it}^f(s)}{\rho-1} + \widehat{F}_{it}(s) \tag{C24}$$

$$\widehat{V}_{it}(s) = \frac{\sigma}{1-\sigma}\hat{Z}_{it}(s) + \frac{1}{\sigma-1}\hat{p}_{it}^v(s) - \frac{1}{\sigma-1}\hat{p}_{it}(s) + \hat{Q}_{it}(s) \tag{C25}$$

$$\widehat{X}_{it}(s) = \frac{\sigma}{1-\sigma}\hat{Z}_{it}(s) + \frac{1}{\sigma-1}\hat{p}_{it}^x(s) - \frac{1}{\sigma-1}\hat{p}_{it}(s) + \hat{Q}_{it}(s) \tag{C26}$$

$$\hat{r}_{it} + \widehat{K}_{it}(s) = \hat{p}_{it}^v(s) + \widehat{V}_{it}(s) \tag{C27}$$

$$\widehat{w}_{it} + \hat{L}_{it}(s) = \hat{p}_{it}^v(s) + \widehat{V}_{it}(s) \tag{C28}$$

$$\widehat{X}_{jit}(s', s) = \frac{1}{\eta-1}\hat{p}_{jt}(s') - \frac{1}{\eta-1}\hat{p}_{it}^x(s) + \widehat{X}_{it}(s) \tag{C29}$$

Define steady-state values of $S_Q^F(ijs) = \frac{F_{ij}(s)}{Q_i(s)}$ and $S_Q^X(ijss') = \frac{X_{ij}(s,s')}{Q_i(s)}$ to have:

$$\hat{Q}_{it}(s) = \sum_{j=1}^N \sum_{s'=1}^S \left(S_Q^F(ijs)\left(\widehat{F}_{ijt}(s)\right) + S_Q^X(ijss')\left(\widehat{X}_{ijt}(s, s')\right)\right) \tag{C30}$$

Define steady-state values of $S_F^C(i) = \frac{C_i}{F_i}$ and $S_F^K(i) = \frac{K_i}{F_i}$ to have:

$$\widehat{F}_{it} = S_F^C(i)\left(\hat{C}_{it}\right) + S_F^K(i)\left(\widehat{K}_{it+1}\right) - (1-\delta)S_F^K(i)\left(\widehat{K}_{it}\right) \tag{C31}$$

Define steady-state value of $S_K^K(is) = \frac{K_i(s)}{K_i}$ to have:

$$\widehat{K}_{it} = \sum_{s=1}^{S} S_K^K(is)\left(\widehat{K}_{it}(s)\right) \tag{C32}$$

Define steady-state value of $S_L^L(is) = \frac{L_i(s)}{L_i}$ to have:

$$\widehat{L}_{it} = \sum_{s=1}^{S} S_L^L(is)\left(\widehat{L}_{it}(s)\right) \tag{C33}$$

Define steady-state value of $S_Q^V(is) = \frac{p_i^v(s)V_i(s)}{p_i(s)Q_i(s)}$ to have:

$$\widehat{Q}_{it}(s) = S_Q^V(is)\left(\widehat{Z}_{it}(s) + \widehat{V}_{it}(s)\right) + \left(1 - S_Q^V(is)\right)\left(\widehat{Z}_{it}(s) + \widehat{X}_{it}(s)\right) \tag{C34}$$

Define steady-state value of $S_X^X\left(jis^{\prime}\ s\right) = \frac{\omega_{ji}^x\left(s^{\prime},s\right)^{1-\eta} X_{ji}\left(s^{\prime},s\right)^{\eta}}{X_i(s)^{\eta}}$ to have:

$$\widehat{X}_{it}(s) = \sum_j \sum_{s^{\prime}} S_X^X\left(jis^{\prime}\ s\right)\left(\widehat{X}_{jit}\left(s^{\prime},s\right)\right) \tag{C35}$$

$$\widehat{V}_{it}(s) = \alpha \widehat{K}_{it}(s) + (1-\alpha)\widehat{L}_{it}(s) \tag{C36}$$

Define steady-state value of $S_F^F(jis) = \frac{\omega_{ji}^f(s)^{1-\rho} F_{ji}(s)^{\rho}}{F_i(s)^{\rho}}$ to have:

$$\widehat{F}_{it}(s) = \sum_j S_F^F(jis)\left(\widehat{F}_{jit}(s)\right) \tag{C37}$$

$$\widehat{F}_{it} = \sum_s \gamma_i(s)\widehat{F}_{it}(s) \tag{C38}$$

Parameters. Following Johnson (2014), we set $\beta = 0.96$, $\delta = 0.1$, $\varepsilon = 4$, $\rho = 0.5$, $\sigma = \eta = 0$, and $\alpha = 0.33$.

Steady-State Values. Steady-state shares in the log-linearized model that are borrowed from World Input-Output Database for the year 2000 are given as follows:

$S_Q^F(ijs) = \frac{F_{ij}(s)}{Q_i(s)} = \frac{p_{it}(s)F_{ij}(s)}{p_{it}(s)Q_i(s)}$ is the steady-state share (in values) of sector s production in country i that is sold as a final good to country j. $S_Q^X\left(ijss^{\prime}\right) = \frac{X_{ij}\left(s,s^{\prime}\right)}{Q_i(s)} = \frac{p_{it}(s)X_{ij}\left(s,s^{\prime}\right)}{p_{it}(s)Q_i(s)}$ is the steady-state share (in values) of sector s production in country i that is as an intermediate input to be further used for the production of sector $\left(s^{\prime}\right)$ in country j. $S_F^C(i) = \frac{C_i}{F_i}$ is the steady-state share of final goods used for consumption in country i. $S_F^K(i) = \frac{K_i}{F_i}$ is the steady-state share of final goods used for investment in country i. $S_K^K(is) = \frac{K_i(s)}{K_i}$ is the steady-state share of capital in country i that is used in sector s. $S_L^L(is) = \frac{L_i(s)}{L_i}$ is the steady-state share of labor in country i that is used in sector s. $S_Q^V(is) = \frac{p_i^v(s)V_i(s)}{p_i(s)Q_i(s)}$ is the steady-state cost share of the domestic input in sector s of country i. $S_X^X(jis^{\prime}\ s) = \frac{\omega_{ji}^x(s^{\prime},s)^{1-\eta}X_{ji}(s^{\prime},s)^{\eta}}{X_i(s)^{\eta}}$ is the steady-state input share of sector $s^{\prime}$ in country j that is used for the production of sector s in country i. $S_F^F(jis) = \frac{\omega_{ji}^f(s)^{1-\rho}F_{ji}(s)^{\rho}}{F_i(s)^{\rho}}$ is the steady-state input share of sector s in country j that is used for the production of final good of sector s in country i. $\gamma_i(s)$ is the share of sector s in the production of the final good.

Productivity process. The FAVAR methodology is connected to the IRBC model through the productivity process. As the FAVAR methodology considers global, sectoral and country-specific factors of productivity, in the IRBC model, we define the following equation for the log-linearized sector-level productivity:

$$\hat{Z}_{it}(s) = \beta_i^G(s)\hat{Z}_t + \beta_i^S(s)\hat{Z}_t(s) + \beta_i^C(s)\hat{Z}_{it} \qquad \text{(C39)}$$

where $\hat{Z}_t$, $\hat{Z}_t(s)$ and $\hat{Z}_{it}$ represent global, sector-specific and country-specific productivity factors, and $\beta_i^G(s)$, $\beta_i^S(s)$ and $\beta_i^C(s)$ represent the coefficients estimated according to Equation (1) by the dynamic factor model.

As the FAVAR methodology utilizes the growth rate of sectoral productivity, we define the growth rate of global productivity $\hat{z}_t$ as follows in the IRBC model:

$$\hat{z}_t = \hat{Z}_t - \hat{Z}_{t-1} \qquad \text{(C40)}$$

It is assumed in the IRBC model that $\hat{z}_t$ follows an AR(1) process according to:

$$\hat{z}_t = \varphi\hat{z}_{t-1} + v_t \qquad \text{(C41)}$$

where φ is the AR(1) coefficient for the global productivity factor, and v_t is the global shock. This can be rewritten by using $\hat{z}_t = \hat{Z}_t - \hat{Z}_{t-1}$ as follows:

$$\hat{Z}_t = (1+\varphi)\hat{Z}_{t-1} - \varphi\hat{Z}_{t-2} + v_t \qquad \text{(C42)}$$

which we use in the model calibration.

In a similar way, for the sector-specific productivity factor, we can write:

$$\hat{Z}_t(s) = \big(1+\varphi(s)\big)\hat{Z}_{t-1}(s) - \varphi(s)\hat{Z}_{t-2}(s) + v_t(s) \qquad \text{(C43)}$$

where $\varphi(s)$ is the sector-specific AR(1) coefficient, and $v_t(s)$ is a sector-specific shock.

Finally, for the country-specific productivity factor, we can write:

$$\hat{Z}_{it} = (1 + \varphi_i)\hat{Z}_{it-1} - \varphi_i \hat{Z}_{it-2} + v_{it} \tag{C44}$$

where φ_i is the country-specific AR(1) coefficient, and v_{it} is the country-i-specific shock.

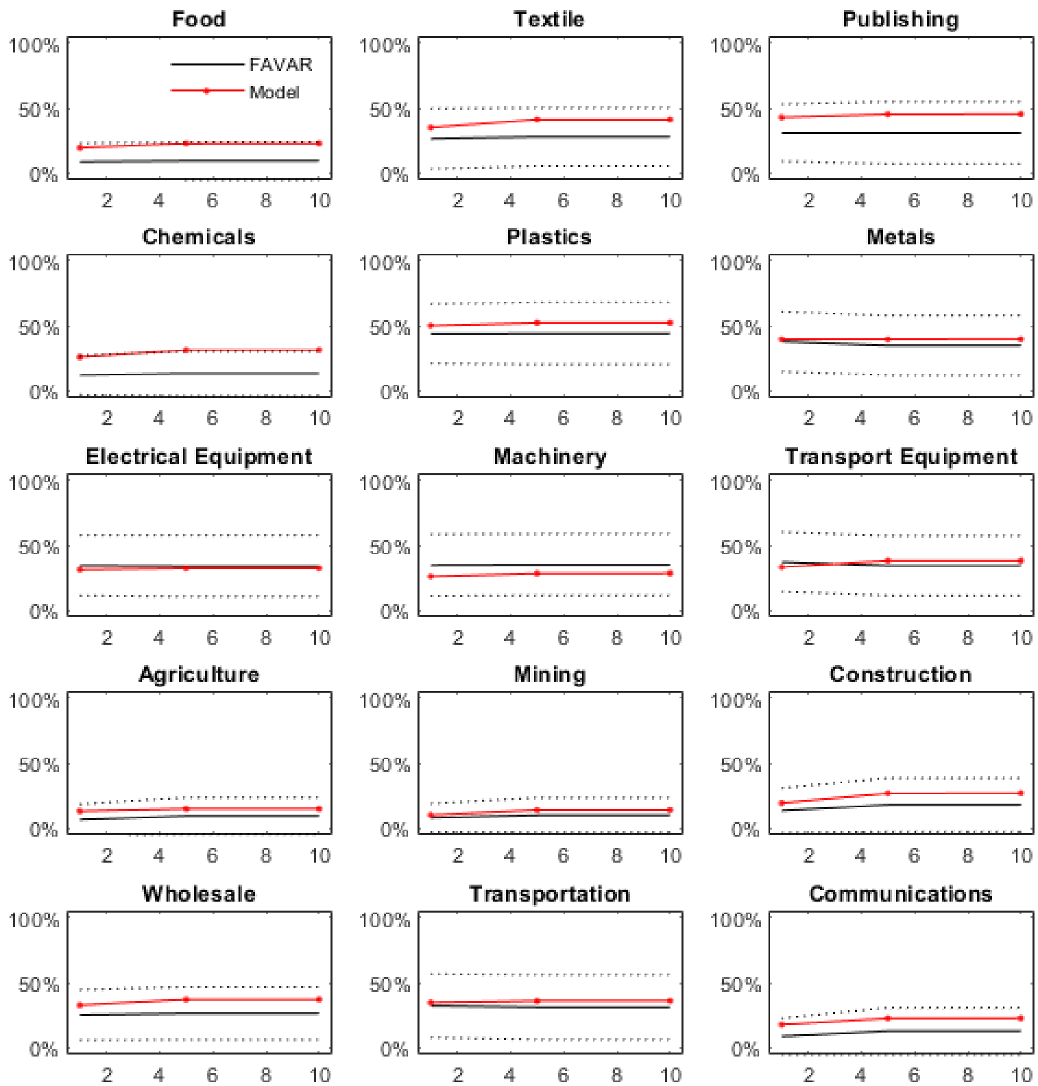
As the estimates of $\beta_i^G(s)$, $\beta_i^S(s)$ and $\beta_i^C(s)$ are borrowed from the dynamic factor model, on top of the parameters borrowed from Johnson (2014) and the steady-state values borrowed from the World Input-Output Database, the only remaining values that are necessary for the model calibration are the AR(1) coefficients of φ, $\varphi(s)$ and φ_i as well as the corresponding sizes of shocks represented by v_t, $v_t(s)$ and v_{it}.

Following studies such as by Christiano et al. (2005), Altig et al. (2011), Boivin and Giannoni (2006), Uribe and Yue (2006), and Dupor et al. (2009), we estimate these remaining values by matching the impulse responses of sector-level output growth to alternative productivity factors in the FAVAR methodology with those in the IRBC model.

The log-linearized model is solved by using Dynare for the same 15 sectors and 13 countries used in the FAVAR methodology.[41] The matching of the impulse responses between the FAVAR methodology and the IRBC model is achieved by using the methodology introduced by Johannes Pfeifer.[42]

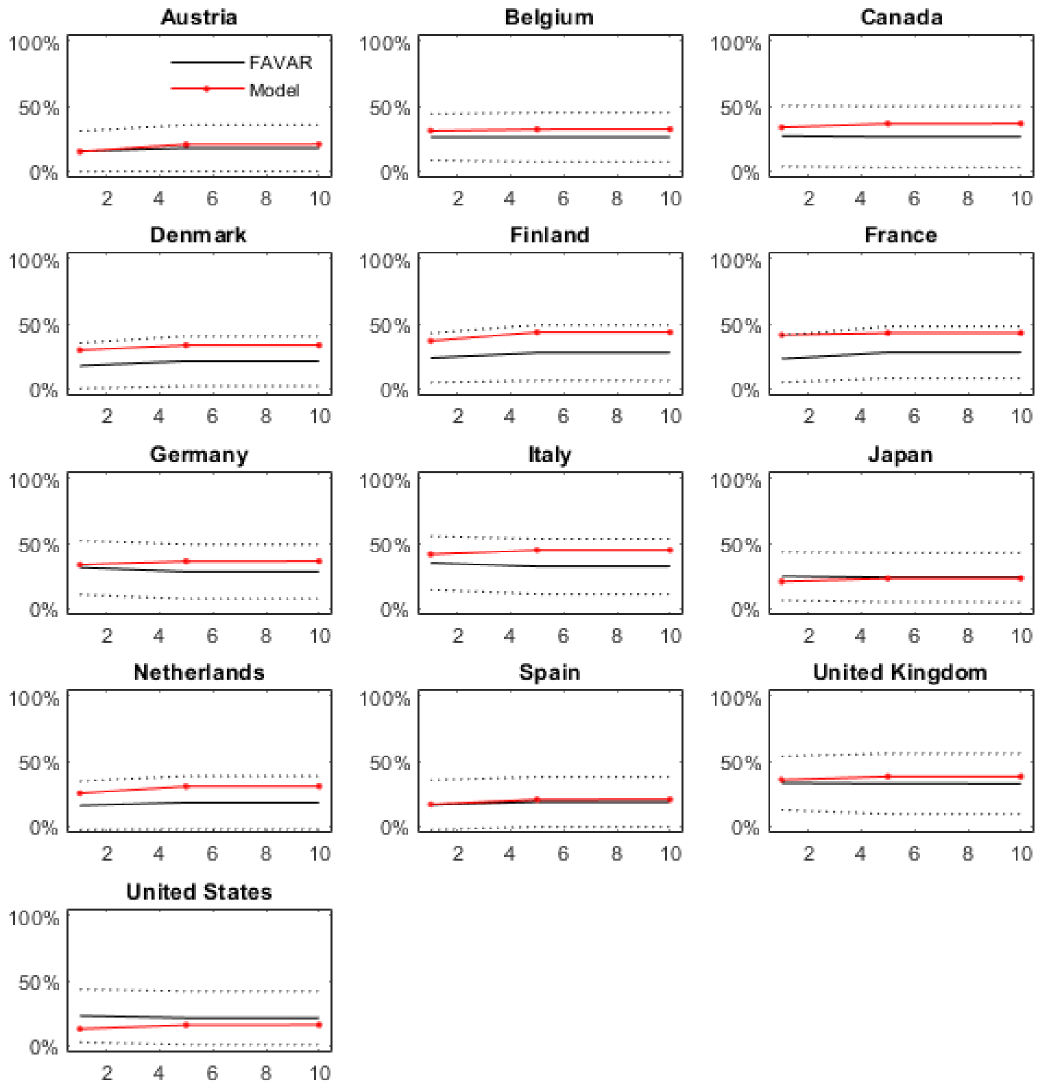
[41] It can be downloaded from https://www.dynare.org/.
[42] These codes can be downloaded from https://github.com/JohannesPfeifer/DSGE_mod/tree/master/RBC_IRF_matching.

Figure C1. Share of sectoral output growth (averages across countries) explained by a common global productivity factor *(Percent)*



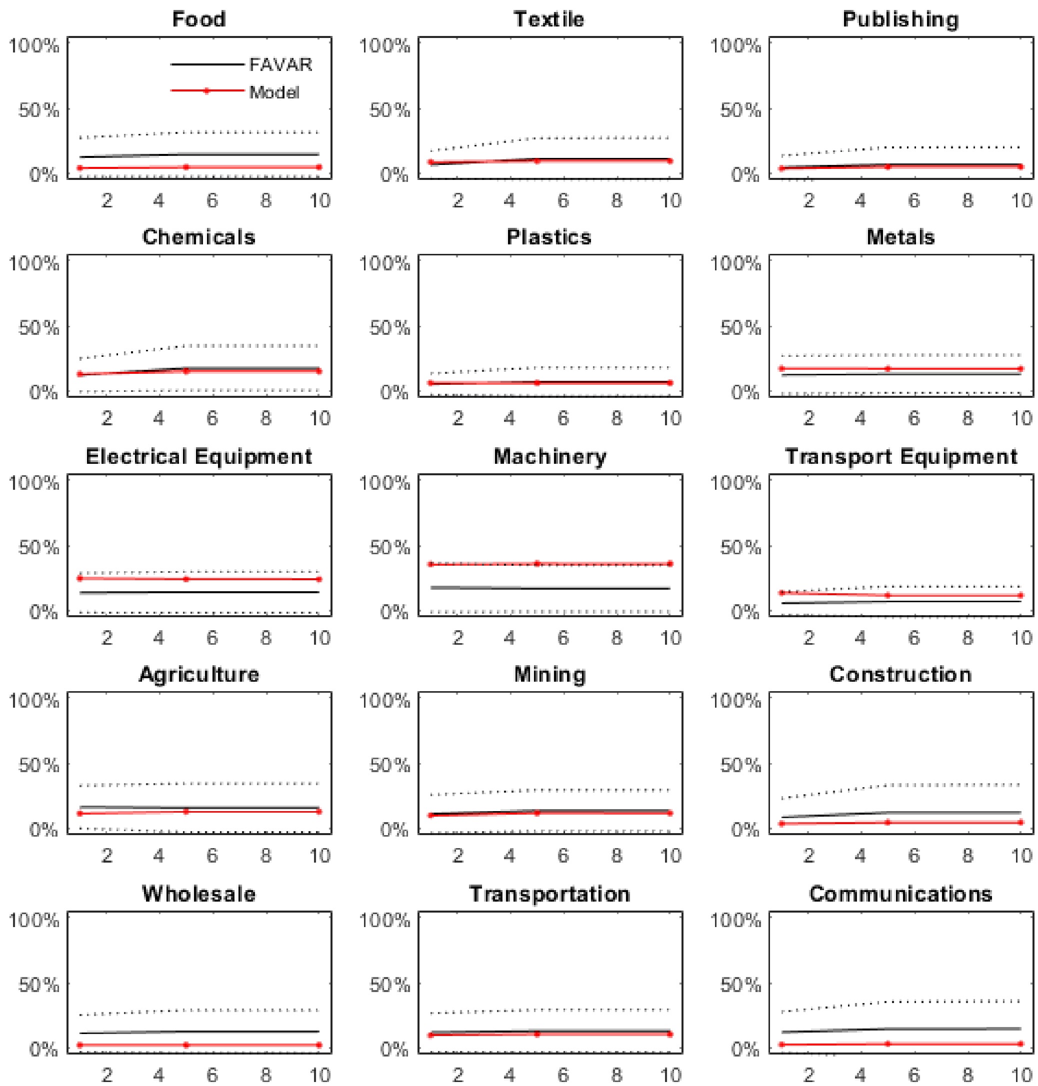
Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: The solid and dashed black lines show the unweighted averages (across countries) of the proportion of forecast error variance explained by a common global productivity factor based on FAVAR methodology. The solid dotted red lines represent the same proportions based on the IRBC model that are normalized such that the total variance explained by all productivity factors in the IRBC model are equalized to the one based on the FAVAR methodology.

Figure C2. Share of sectoral output growth (averages across sectors) explained by a common global productivity factor *(Percent)*



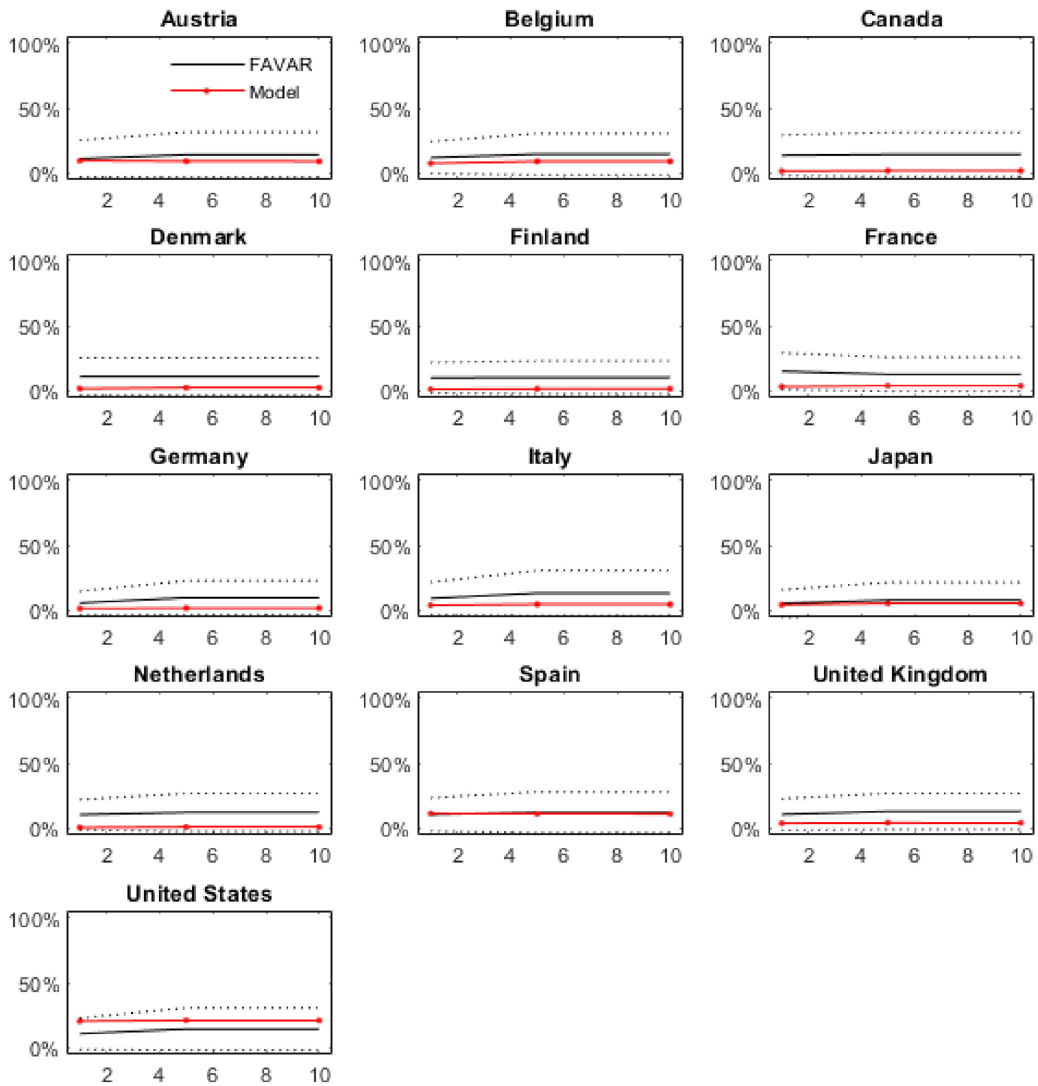
Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: The solid and dashed black lines show the unweighted averages (across sectors) of the proportion of forecast error variance explained by a common global productivity factor based on FAVAR methodology. The solid dotted red lines represent the same proportions based on the IRBC model that are normalized such that the total variance explained by all productivity factors in the IRBC model are equalized to the one based on the FAVAR methodology.

Figure C3. Share of sectoral output growth (averages across countries) explained by sector-specific productivity factors *(Percent)*



Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: The solid and dashed black lines show the unweighted averages (across countries) of the proportion of forecast error variance explained by sector-specific productivity factors based on FAVAR methodology. The solid dotted red lines represent the same proportions based on the IRBC model that are normalized such that the total variance explained by all productivity factors in the IRBC model are equalized to the one based on the FAVAR methodology.

Figure C4. Share of sectoral output growth (averages across sectors) explained by country-specific productivity factors *(Percent)*



Sources: Statistics Canada, EU KLEMS, World KLEMS, 1981-2015.
Notes: The solid and dashed black lines show the unweighted averages (across sectors) of the proportion of forecast error variance explained by country-specific productivity factors based on FAVAR methodology. The solid dotted red lines represent the same proportions based on the IRBC model that are normalized such that the total variance explained by all productivity factors in the IRBC model are equalized to the one based on the FAVAR methodology.

References

Acemoglu, Daron, Ufuk Akcigit, and William Kerr. 2016. "Networks and the Macroeconomy: An Empirical Exploration" *NBER/Macroeconomics Annual (University of Chicago Press)*, 30(1): 273-335.

Acemoglu, Daron, Vasco M. Carvalho, Asuman Ozdaglar, and Alireza Tahbaz-Salehi. 2012. "The Network Origins of Aggregate Fluctuations" *Econometrica*, 80(5): 1977-2016.

Altig, D., Christiano, L.J., Eichenbaum, M. and Linde, J., 2011. “Firm-specific capital, nominal rigidities and the business cycle.” *Review of Economic dynamics*, 14(2), pp.225-247.

Ambler, Steve, Cardia, Emanuela, and Zimmermann, Christian. 2004. "International business cycles: What are the facts?," *Journal of Monetary Economics*, Elsevier, vol. 51(2), pages 257-276, March.

Atalay, Enghin. 2017. "How Important are Sectoral Shocks?” *American Economic Journal: Macroeconomics*, 9(4): 254-280.

Backus, David K., Patrick J. Kehoe, and Finn E. Kydland. 1992. "International Real Business Cycles” *Journal of Political Economy*, 100(4): 745.

Barrot, Jean-Noel and Julien Sauvagnat. 2016. "Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks” *Quarterly Journal of Economics*, 131(3): 1543-1592.

Basu, Susanto, John G. Fernald, and Miles S. Kimball. 2006. "Are Technology Improvements Contractionary?” *American Economic Review*, 96(5): 1418-1448.

Bernanke, Ben S., Jean Boivin, and Piotr Eliasz. 2005. "Measuring the Effects of Monetary Policy: A Factor-Augmented Vector Autoregressive (FAVAR) Approach” *Quarterly Journal of Economics*, 120(1): 387-422.

Bloom, Nicholas. 2009. “The Impact of Uncertainty Shocks”, *Econometrica* 77(3), 623–685.

Boivin, J. and Giannoni, M.P., 2006. “Has monetary policy become more effective?” *The Review of Economics and Statistics*, 88(3), pp.445-462.

Bonadio, Barthelemy, Zhen Huo, Andrei A. Levchenko, and Nitya Pandalai-Nayar. 2020 “Global Supply Chains in the Pandemic.” NBER Working Paper 27224.

Canova, Fabio. 2005. “The transmission of US shocks to Latin America.” *Journal of Applied Econometrics* 20 (2):229–251.

Cette, Gilbert, John Fernald, and Benoit Mojon. 2016. “The Pre-Great Recession Slowdown in Productivity” *European Economic Review*, 88: 3-20.

Christiano, L.J., Eichenbaum, M. and Evans, C.L., 2005. “Nominal rigidities and the dynamic effects of a shock to monetary policy.” *Journal of political Economy*, 113(1), pp.1-45.

Corsetti, Giancarlo, Luca Dedola, and Sylvain Leduc. 2014. “The International Dimension of Productivity and Demand Shocks in the US Economy.” *Journal of the European Economic Association* 12 (1):153–176.

Costello, Donna M. 1993. "A Cross-Country, Cross-Industry Comparison of Productivity Growth" *Journal of Political Economy*, 101(2): 207.

Crucini, Mario J., M. Ayhan Kose, and Christopher Otrok. 2011. "What are the Driving Forces of International Business Cycles?" *Review of Economic Dynamics*, 14(1): 156-175.

Da-Rocha, Jos, and Diego Restuccia. 2006. "The Role of Agriculture in Aggregate Business Cycles" *Review of Economic Dynamics*, 9(3): 455-482.

Dedola, Luca, and Neri, Stefano. 2007. "What does a technology shock do? A VAR analysis with model-based sign restrictions," *Journal of Monetary Economics*, Elsevier, vol. 54(2), pages 512-549, March.

Dupor, B., Han, J. and Tsai, Y.C., 2009. "What do technology shocks tell us about the New Keynesian paradigm?" *Journal of Monetary Economics*, 56(4), pp.560-569.

di Giovanni, Julian, Andrei A. Levchenko, and Isabelle Mejean. 2014. "Firms, Destinations, and Aggregate Fluctuations" *Econometrica*, 82(4): 1303-1340.

Everts, Martin. 2006. "Sectoral and Industrial Business Cycles" Discussion Paper, University of Bern, Department of Economics.

Farhi, Emmanuel, and Ivan Werning. 2016. "A Theory of Macroprudential Policies in the Presence of Nominal Rigidities." *Econometrica* 84 (5): 1645-1704.

Fernald, John, Robert Inklaar, and Dimitrije Ruzic. 2023. "The Productivity Slowdown in Advanced Economies: Common Shocks or Common Trends?," Federal Reserve Bank of San Francisco Working Paper 2023-07. Available at https://doi.org/10.24148/wp2023-07

Fernald, John G. 2015. "Productivity and Potential Output before, during, and After the Great Recession" *NBER/Macroeconomics Annual (University of Chicago Press)*, 29(1): 1-51.

Foerster, Andrew T., Pierre-Daniel G. Sarte, and Mark W. Watson. 2011. "Sectoral Versus Aggregate Shocks: A Structural Factor Analysis of Industrial Production" *Journal of Political Economy*, 119(1): 1-38.

Foerster, Andrew T., Pierre-Daniel G. Sarte, Andreas Hornstein, and Mark W. Watson. 2019. "Aggregate Implications of Changing Sectoral Trends," Working Paper 19-11, Federal Reserve Bank of Richmond, revised 28 May 2019.

Frankel, Jeffrey A. and Andrew K. Rose. 1998. "The Endogeneity of the Optimum Currency Area Criteria." *Economic Journal* 108 (449):1009–25.

Glick, Reuven, and Kenneth Rogoff. 1995. "Global versus Country-specific Productivity Shocks and the Current Account", *Journal of Monetary Economics*, 35, pp. 159-192.

Gordon, Robert J., and Hassan Sayed. 2019. "The industry anatomy of the transatlantic productivity slowdown," NBER Working Paper No 25703.

Hirata, Hideaki, M. Ayhan Kose, Christopher Otrok, and Marco E. Terrones. 2013. "Global House Price Fluctuations: Synchronization and Determinants" *NBER International Seminar on Macroeconomics*, 9(1): 119-166.

Horvath, Michael. 2000. "Sectoral Shocks and Aggregate Fluctuations" *Journal of Monetary Economics*, 45(1): 69-106.

Huo, Zhen, Andrei A. Levchenko, and Nitya Pandalai-Nayar. 2020. "International Comovement in the Global Production Network." NBER Working Paper 25978.

Imbs, Jean. 1999. "Technology, growth and the business cycle." *Journal of Monetary Economics* 44 (1):65 – 80.

Johnson, Robert C. 2014. "Trade in Intermediate Inputs and Business Cycle Comovement." *American Economic Journal: Macroeconomics* 6 (4):39–83.

Karadimitropoulou, Aikaterini, and Miguel Leon-Ledesma. 2013. "World, Country, and Sector Factors in International Business Cycles" *Journal of Economic Dynamics and Control*, 37(12): 2913-2927.

Karadimitropoulou, Aikaterini, 2018. "Advanced economies and emerging markets: Dissecting the drivers of business cycle synchronization," *Journal of Economic Dynamics and Control*, Elsevier, vol. 93(C), pages 115-130.

Kiyotaki, Nobuhiro and John Moore. 1997. "Credit Cycles", *Journal of Political Economy*, 105: 2, 211-248.

Kose, M. Ayhan, and Marco E. Terrones. 2015. *Collapse and Revival: Understanding Global Recessions and Recoveries.* Washington DC: International Monetary Fund.

Kose, M. Ayhan, Christopher Otrok, and Eswar Prasad. 2012. "Global Business Cycles: Convergence Or Decoupling?" *International Economic Review*, 53(2): 511-538.

Kose, M. Ayhan, Christopher Otrok, and Charles H. Whiteman. 2008 "Understanding the Evolution of World Business Cycles" *Journal of International Economics*, Vol. 75, No. 1, pp. 110–30.

Kose, M. Ayhan, Christopher Otrok, and Charles H. Whiteman. 2003. "International Business Cycles: World, Region, and Country-Specific Factors" *American Economic Review*, 93(4): 1216-1239.

Kose, M. Ayhan and Kei-Mu Yi. 2006. "Can the Standard International Business Cycle Model Explain the Relation Between Trade and Comovement." *Journal of International Economics* 68 (2): 267–295.

Kydland, Finn and Edward Prescott. 1982. "Time to Build and Aggregate Fluctuations", *Econometrica*, November, 50(6), pp. 1345–1370.

Lazear, Edward P. 2019. "Productivity and wages: common factors and idiosyncrasies across countries and industries", NBER Working Paper No. 26428. Liao, Wei, and Ana Maria Santacreu. 2015. "The trade comovement puzzle and the margins of international trade", *Journal of International Economics*, 96 (2): 266-288

Li, N. and Martin, V.L., 2019. Real sectoral spillovers: A dynamic factor analysis of the great recession. *Journal of Monetary Economics*, *107*, pp.77-95.

Long, J. B., and C. I. Plosser. 1987. "Sectoral vs. Aggregate Shocks In The Business Cycle." *American Economic Review*, 77(2): 333-336.

Long, John B. and Charles I. Plosser. 1983. "Real Business Cycles" *Journal of Political Economy*, 91(1): 39-69.

Norrbin, Stefan C., and Don E. Schlagenhauf. 1996. "The Role of International Factors in the Business Cycle: A Multi-Country Study" *Journal of International Economics*, 40(1): 85-104.

Obstfeld, Maurice. 1994. "Risk-taking, Global Diversification, and Growth." *American Economic Review* 84: 1310–1329.

O'Mahony, Mary, and Marcel P. Timmer. 2009. "Output, Input and Productivity Measures at the Industry Level: The EU KLEMS Database" *Economic Journal*, 119(538): F374-F403.

Oviedo, P. Marcelo, and Rajesh Singh. 2013. "Investment Composition and International Business Cycles" *Journal of International Economics*, 89(1): 79-95.

Peersman, Gert, and Roland Straub. 2009. "Technology Shocks And Robust Sign Restrictions In A Euro Area Svar," *International Economic Review*, vol. 50(3), pages 727-750, August.

Plosser, C. I. 1989. "Understanding Real Business Cycles," *Journal of Economic Perspectives*, American Economic Association, vol. 3(3), pages 51-77, Summer.

Stock, James H. and Mark W. Watson. 2016. "Dynamic Factor Models, Factor-Augmented Autoregressions, and Structural Vector Autoregressions in Macroeconomics" Chap. 8 in Handbook of Macroeconomics, vol. 2, edited by John B. Taylor and Harald Uhlig, 415–526. North Holland: Elsevier.

Stockman, Alan C. 1988. "Sectoral and National Aggregate Disturbances to Industrial Output in Seven European Countries" *Journal of Monetary Economics*, 21(2): 387-409.

Syverson, Chad. 2017. "Challenges to Mismeasurement Explanations for the US Productivity Slowdown." *Journal of Economic Perspectives*, 31(2): 165-86.

Uribe, M. and Yue, V.Z., 2006. "Country spreads and emerging countries: Who drives whom?" *Journal of international Economics*, 69(1), pp.6-36.

Vigfusson, Robert. 2008. "How does the Border Affect Productivity? Evidence from American and Canadian Manufacturing Industries" *Review of Economics & Statistics*, 90(1): 49-64.

vom Lehn, C. and Winberry, T., 2022. The investment network, sectoral comovement, and the changing US business cycle. The Quarterly Journal of Economics, 137(1), pp.387-433.