

# Revisiting Productivity Dynamics in Europe: A New Measure of Utilization-Adjusted TFP Growth

## Online Appendix

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### A Methodological details

#### A.1 Full model solution

**Euler equations** The value function  $V$  for the problem described in (3) holds the Bellman equation:

$$\begin{aligned}
 V_t &= \min \left( w_t^F \Gamma_F (H_t^F) N_t^F + w_t^V \Gamma_V (H_t^V) N_t^V + q_t^F \Lambda_F (E_t^F) H_t^F N_t^F \right. \\
 &\quad \left. + q_t^V \Lambda_V (E_t^V) H_t^V N_t^V + P_{M,t} M_t + P_{I,t} I_t + \mathbb{E}_t \left( \frac{1}{1+r_{t+1}} V_{t+1} \right) \right) \\
 \text{s.t. } Y_t &= Z_t (K_t)^{\alpha_K} (E_t^F H_t^F N_t^F)^{\alpha_L^F} (E_t^V H_t^V N_t^V)^{\alpha_L^V} (M_t)^{\alpha_M}, \\
 K_{t+1} &= (1 - \delta_K) K_t + I_t, \\
 N_{t+1}^F &= (1 - \delta_N^F) N_t^F + A_t^F
 \end{aligned} \tag{A.1}$$

where  $V_t \equiv V(K_t, N_t^F, Z_t, Y_t, r_t, w_t^F, w_t^V, q_t^F, q_t^V, P_{M,t}, P_{I,t})$ . The first-order conditions for  $K_{t+1}$  and  $N_{t+1}^F$  are

$$P_{I,t} + \mathbb{E}_t \left( \frac{1}{1+r_{t+1}} \frac{\partial V_{t+1}}{\partial K_{t+1}} \right) = 0, \tag{A.2}$$

$$\mathbb{E}_t \left( \frac{1}{1+r_{t+1}} \frac{\partial V_{t+1}}{\partial N_{t+1}^F} \right) = 0. \tag{A.3}$$

The envelope conditions for the problem are

$$\frac{\partial V_t}{\partial K_t} = - (1 - \delta_K) P_{I,t} - \lambda_t \frac{\alpha_K Y_t}{K_t}, \tag{A.4}$$

$$\frac{\partial V_t}{\partial N_t^F} = \tilde{w}_t^F - \lambda_t \frac{\alpha_L^F Y_t}{N_t^F}. \tag{A.5}$$

Using these expressions to substitute out the derivatives of the value function in the first-order conditions, we obtain the Euler equations in the main text.

**BGP solution** The BGP is defined as a situation in which output, TFP and factor prices grow at a constant rate, and the relative price of hours per worker with respect to worker

effort is constant. Note that a BGP does not require output, TFP and factor prices to grow at the same rate. As we show in this section, the firm chooses capital, employment and materials to grow at a constant rate on the BGP, and hours per worker and effort per hour to be constant.

On the BGP, the first-order condition for materials becomes

$$P_{M,t}^* = \alpha_M \lambda_t^* \frac{Y_t^*}{M_t^*}. \quad (\text{A.6})$$

The first-order condition for hours, effort and employment of any type  $\ell \in \{F, V\}$  are

$$w_t^{\ell*} \Gamma'_\ell (H^{\ell*}) N_t^{\ell*} + q_t^{\ell*} \Lambda_\ell (E^{\ell*}) N_t^{\ell*} = \alpha_L^\ell \lambda_t^* \frac{Y_t^*}{H^{\ell*}}; \quad (\text{A.7})$$

$$q_t^{\ell*} \Lambda'_\ell (E^{\ell*}) H^{\ell*} N_t^{\ell*} = \lambda_t^* \alpha_L^\ell \frac{Y_t^*}{E^{\ell*}}; \quad (\text{A.8})$$

$$w_t^{\ell*} \Gamma_\ell (H^{\ell*}) + q_t^{\ell*} \Lambda_\ell (E^{\ell*}) H^{\ell*} = \alpha_L^\ell \lambda_t^* \frac{Y_t^*}{N_t^{\ell*}}. \quad (\text{A.9})$$

Combining these equations shows that the BGP levels of effort per hour and hours per worker hold

$$\frac{\Gamma'_\ell (H^{\ell*}) H^{\ell*}}{\Gamma_\ell (H^{\ell*})} = 1, \quad (\text{A.10})$$

$$\frac{\Lambda'_\ell (E^{\ell*}) E^{\ell*}}{\Lambda_\ell (E^{\ell*})} = 1 + \frac{w_t^{\ell*} \Gamma'_\ell (H^{\ell*})}{q_t^{\ell*} \Lambda'_\ell (E^{\ell*})}, \quad (\text{A.11})$$

The first condition is intuitive. Employment and hours enter the production function symmetrically. The elasticity of the wage bill with respect to employment is 1 by definition, so the firm chooses hours such that the elasticity of the wage bill with respect to hours is 1 as well. Under some regularity conditions for the cost functions  $\Gamma$  and  $\Lambda$ , and the assumption that wages and effort costs grow at the same rate, these equations pin down a unique solution for BGP effort and hours.

Finally, the Euler equation for capital is

$$R^* = \alpha_K \lambda_t^* \frac{Y_t^*}{P_{I,t-1}^* K_t^*}. \quad (\text{A.12})$$

On the BGP, total costs of production for factors used in period  $t$  are

$$\begin{aligned} TC_t^* &= \tilde{w}_t^{F*} N_t^{F*} + \tilde{w}_t^{V*} N_t^{V*} + P_{M,t}^* M_t^* + \left( (1+r^*) P_{I,t-1}^* - (1-\delta_K) P_{I,t}^* \right) K_t^* \\ &= \tilde{w}_t^{F*} N_t^{F*} + \tilde{w}_t^{V*} N_t^{V*} + P_{M,t}^* M_t^* + R^* P_{I,t-1}^* K_t^* \end{aligned} \quad (\text{A.13})$$

Replacing Equations (A.6), (A.9) and (A.12) into this expression, and using the defini-

tion of the rental rate, it comes immediately that total cost is

$$TC_t^* = \lambda_t^* Y_t^* \quad (\text{A.14})$$

Thus, on the balanced growth path, average cost is equal to marginal cost. Using this result together with the BGP first order conditions for materials, employment and labour, we get equations (11) to (13) in the main text.

## A.2 Comparing our model to Basu *et al.* (2006)

The model in Section 2 differs slightly from the one in Basu and Fernald (2001) and Basu *et al.* (2006). Problem (A.15) summarizes the BFK model (as shown in equations (6) to (9) of Basu *et al.* (2006), and using our notation for an easier comparison). The representative firm solves

$$\begin{aligned} \min \mathbb{E}_0 \left[ \sum_{t=0}^{+\infty} \left( \prod_{s=1}^t \left( \frac{1}{1+r_s} \right) \right) \left( w_t \Gamma(H_t, E_t) V(U_t) N_t + P_{M,t} M_t + \right. \right. \\ \left. \left. w_t N_t \Psi \left( \frac{A_t}{N_t} \right) + P_{I,t} K_t \Phi \left( \frac{I_t}{K_t} \right) \right) \right] \\ \text{s.t.} \quad Y_t = F(Z_t, U_t K_t, E_t H_t N_t, M_t), \\ K_{t+1} = (1 - \delta_K) K_t + I_t, \\ N_{t+1} = N_t + A_t, \end{aligned} \quad (\text{A.15})$$

where  $U_t$  is capital utilization and  $V$  is an increasing and convex function. Most differences between this setup and ours do not matter for measurement.

1. BFK consider a general production function  $F$ , while we impose a Cobb-Douglas production function. This difference is irrelevant, as BFK log-linearize around the BGP. This makes their effective production function log-linear with constant elasticities (i.e., Cobb-Douglas).
2. BFK consider adjustment costs to capital and employment, captured by the functions  $\Phi$  and  $\Psi$ , while we abstract from such costs in our baseline analysis. However, BFK assume that industries are always close to a BGP on which marginal adjustment costs are zero. Thus, adjustment costs are negligible and can be ignored for TFP measurement (this assumption is relaxed in Basu *et al.* (2001)).
3. BFK consider the utilization rate of capital,  $U_t$ , as an independent production factor, while we consider it as an endogenous outcome (and therefore omit it from our reduced-form production function). This distinction is irrelevant in practice, as BFK argue that both the utilization rate of capital and worker effort are (up to a first-order approximation) linearly related to hours per worker. Thus, irrespective of whether there are one or two unobservable production factors, TFP growth can be obtained by a regression of the Solow residual on changes in hours per worker. Likewise, in our approach, we could easily introduce capital utilization as a production factor: as long

as it is also linearly related to the utilization survey, our estimation equation would remain the same.

However, there are also two more important differences. First, we impose constant returns to scale, while BFK allow for non-constant returns to scale. Thus, [Basu et al. \(2006\)](#) actually estimate a returns to scale parameter and a utilization adjustment parameter for every industry. However, their results indicate that most industries are close to constant returns to scale. Therefore, they impose this restriction from the outset in later work. For instance, the famous quarterly series for utilization-adjusted TFP growth in the United States introduced in [Fernald \(2014a\)](#) assumes constant returns to scale from the outset.

Second, we assume that there are two types of labour, and that there might be shocks to the relative cost of hours per worker and effort. As we show in the main text, hours per worker might not be an ideal proxy for effort in this more general setup.

### A.3 The link between worker effort and capacity utilization

In this section, we show how different assumptions on full capacity variable input choices generate a close relationship between changes in effort and changes in capacity utilization.

The simplest assumption delivering this result is that full capacity production uses current variable factor proportions (e.g., if the firm currently uses 2 hours of variable labour for every MW of electricity, it also uses 2 hours of variable labour for every MW of electricity in full capacity).<sup>35</sup> Formally, for any two variable inputs  $V_1$  and  $V_2$ ,  $V_1/V_2 = V_1^{FC}/V_2^{FC}$ .

Combining this assumption with equation (18), we get

$$\alpha_L^V \left( dE_t^V - dE_t^{V,FC} \right) + \alpha_L^F \left( dE_t^F - dE_t^{F,FC} \right) = \beta dCU_t, \quad (\text{A.16})$$

where  $\beta = (\alpha_L^V + \alpha_L^F) \cdot (3\alpha_L^V + 2\alpha_L^F + \alpha_M)$ . In other words, there is a direct relation between total changes in effort (relative to full capacity effort) and changes in capacity utilization. When changes in full capacity effort over time are small with respect to changes in actual effort (which seems reasonable), changes in capacity utilization are approximately linearly related to changes in worker effort, justifying equation (19).

Importantly, these assumptions are not the only ones to deliver a tight link between effort and capacity utilization. We obtain the same result when we assume that in order to produce full capacity output, firms minimize costs, taking current input prices as given. That is, we again do not take a stand on how firms choose the level of full capacity production, but only impose that they produce with an optimal combination of inputs. Moreover, we need to assume functional forms for the cost functions of adjusting hours per worker and effort, imposing

$$\Gamma_\ell \left( H_t^\ell \right) = 1 + \left( H_t^\ell \right)^{c_\Gamma} \quad \text{and} \quad \Lambda_\ell \left( E_t^\ell \right) = \left( E_t^\ell \right)^{c_\Lambda}, \quad (\text{A.17})$$

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<sup>35</sup>This approach sidesteps the issue of how firms compute full capacity production. As [Shapiro \(1989\)](#) has argued eloquently, the level of full capacity production is difficult to define in a consistent way with a neoclassical production function. As our example shows, we do not have to take a stand on this issue.

where  $c_\Gamma > 1$  and  $c_\Lambda > 1$  are parameters. The intercept in  $\Gamma_\ell$  implies that firms need to pay workers even if they work zero hours, and is needed for a well-defined solution.

Now, we can solve explicitly for variable input choices as a function of variable input prices, fixed inputs, TFP and output. Using the first-order conditions in Section 2, we obtain

$$E_t^\ell = \left( \frac{w_t^\ell}{q_t^\ell} \right)^{\frac{1}{c_\Lambda}} \left( H_t^\ell \right)^{\frac{c_\Gamma-1}{c_\Lambda}}, \quad (\text{A.18})$$

$$\lambda_t = \Theta (Y_t)^{\frac{1-\gamma}{\gamma}} \left( \frac{K_t^{-\alpha_K}}{Z_t} \left( (w_t^V)^{c_\Gamma-1} q_t^V \right)^{\frac{\alpha_L^V}{c_\Lambda}} \left( (w_t^F)^{\frac{c_\Lambda-1}{c_\Gamma}} q_t^F (N_t^F)^{-\frac{(c_\Lambda-1)(c_\Gamma-1)}{c_\Gamma}} \right)^{\frac{\alpha_L^F}{c_\Lambda}} (P_{M,t})^{\alpha_M} \right)^{\frac{1}{\gamma}}, \quad (\text{A.19})$$

where  $\gamma \equiv \alpha_M + \alpha_L^V + \frac{c_\Lambda+c_\Gamma-1}{c_\Lambda c_\Gamma} \alpha_L^F$ , and  $\Theta$  is a constant. Note that the constant  $\gamma$  is smaller than 1, and that the marginal cost of production is therefore increasing in output. Indeed, in the short run, there are decreasing returns to scale, as some factors are fixed.

When firms choose full capacity output by minimizing prices and assuming that factor prices, fixed factors and productivity are at their current level, equation (A.19) implies

$$\frac{\lambda_t}{\lambda_t^{FC}} = \left( \frac{Y_t}{Y_t^{FC}} \right)^{\frac{1-\gamma}{\gamma}}. \quad (\text{A.20})$$

Combining this with the first-order condition for effort, we get

$$\frac{E_t^\ell}{E_t^{\ell,FC}} = (CU_t)^{\frac{c_\Gamma-1}{c_\Gamma c_\Lambda \gamma}}. \quad (\text{A.21})$$

From this, we directly obtain

$$\alpha_L^V \left( dE_t^V - dE_t^{V,FC} \right) + \alpha_L^F \left( dE_t^F - dE_t^{F,FC} \right) = \beta dCU_t, \quad (\text{A.22})$$

where  $\beta = (\alpha_L^V + \alpha_L^F) \frac{c_\Gamma-1}{c_\Gamma c_\Lambda \gamma}$ . This is again equation (A.16), with a different value for  $\beta$ .

## A.4 Aggregation

The standard method to aggregate industry-level TFP growth is due to [Hulten \(1978\)](#) and uses Tornqvist-Domar weights, which depend on each industry's ratio of gross output to aggregate value added.<sup>36</sup>

[Baqaee and Farhi \(2019\)](#) have recently pointed out that this method is flawed in the presence of markups.<sup>37</sup> First, Tornqvist-Domar weights underestimate the contribution of

<sup>36</sup>Precisely, aggregate TFP growth is given by  $dZ_t = \sum_{i=1}^I \frac{1}{2} (\lambda_{i,t-1} + \lambda_{i,t}) dZ_{i,t}$ , where  $\lambda_{i,t}$  is the ratio of industry  $i$ 's gross output to aggregate value added in year  $t$ .

<sup>37</sup>[Rotemberg and Woodford \(1995\)](#) and [Basu and Fernald \(2002\)](#) made similar points in earlier papers.

upstream industries to aggregate TFP growth. Intuitively, when downstream producers apply markups, the ratio of upstream producer sales to aggregate value added underestimates their importance for production. Second, when markups are heterogeneous across industries and factors are mobile, changes in the resource allocation affect aggregate TFP growth. As our estimation allows for positive profits (and thus for markups), we rely on the Baqaee-Farhi results to aggregate our TFP series, computing

$$dZ_t = \sum_{i=1}^I \frac{1}{2} \left( \tilde{\lambda}_{i,t-1} + \tilde{\lambda}_{i,t} \right) dZ_{i,t}, \quad (\text{A.23})$$

where  $\tilde{\lambda}_{i,t-1}$  is the cost-based Domar weight of industry  $i$ . These weights are defined by Proposition 1 in Baqaee and Farhi (2019), which states

$$[\tilde{\lambda}_t, \tilde{\Lambda}_t] = \mathbf{b}'_t \left( \mathbf{I} - \tilde{\mathbf{\Omega}}_t \right)^{-1}. \quad (\text{A.24})$$

With  $I$  industries and  $F$  production factors,  $\mathbf{b}_t$  is an  $(I + F) \times 1$  vector. Its  $I$  first entries contain the share of each industry in total consumption (i.e., element  $i$  is  $p_{it}c_{it} / \sum_{j=1}^I p_{jt}c_{jt}$ ). The last  $F$  entries are equal to 0.  $\tilde{\mathbf{\Omega}}_t$ , in turn, is a cost-based input-output matrix. That is, it is an  $(I + F) \times (I + F)$  matrix in which the element in line  $l$  and column  $c$  is equal to the share of costs of industry  $l$  spend on output (or factor)  $c$ . The last  $F$  rows of the matrix are equal to 0. That is, factors are treated like industries which do not use any inputs. Performing the matrix operation described in equation (A.24) yields a  $(I + F) \times 1$  vector, whose first  $I$  elements are the cost-based industry Domar weights  $\tilde{\lambda}_t$ . The last  $F$  elements, denoted  $\tilde{\Lambda}_t$ , are the cost-based factor Domar weights.

When implementing this formula, we assume that  $\tilde{\mathbf{\Omega}}_t$  does not change over time. This is due to data limitations, as we do not have input-output tables for every year of our sample.<sup>38</sup> We then split up total spending on intermediate inputs into spending on inputs from different industries by using the input shares from country-specific input-output tables for the year 2010.

To compute consumption shares, we get consumption for each industry as the difference between the industry's gross output and the use of that output as an input for other industries. To compute the latter, we get the level of intermediate output spending of each industry  $i$  on goods from another industry  $j$  in year  $t$  by multiplying the total spending on intermediates of industry  $i$  in year  $t$  (from EU KLEMS) with the share of intermediate spending of industry  $i$  which goes to goods from industry  $j$  (from input-output tables, described in Appendix B.7).<sup>39</sup>

It is worth noting that our aggregation procedure implicitly assumes that there are no imports of intermediate goods, that is, that all intermediate inputs come from domestic sources. Relaxing this assumption and taking into account international linkages is beyond

<sup>38</sup>To be consistent, we also assume that the cost shares of production factors (capital and labour) are constant over time, and equal to their BGP level. For simplicity, we consider here just one type of capital and one type of labour, whose cost share is the sum of the cost shares of the different capital and labour types.

<sup>39</sup>In the rare cases in which we obtain negative values for consumption, we set these to zero.

the scope of this paper.

Moreover, while our measure of aggregate TFP growth defined in equation (A.23) correctly weighs the contribution of each industry to aggregate TFP growth, it abstracts from changes in the resource allocation. Conceptually, this choice is equivalent to assuming that all production factors are industry-specific. In the data, there is indeed considerable evidence for obstacles to reallocation across industries in the short and medium run (Ramey and Shapiro (2001); Autor *et al.* (2016)). Even if some resources are reallocated, these changes are gradual and therefore unlikely to affect the cyclical properties of our aggregate TFP series. In line with this argument, Baqaee and Farhi find that the contribution of between-industry reallocation to aggregate TFP growth is essentially zero in the US.<sup>40</sup>

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<sup>40</sup>In practice, computing the contribution of reallocation to productivity growth would require taking a stand on reallocation costs, and computing a time series of markups (while we compute a time series for profit shares, these do not directly translate into markups, as our production function has decreasing returns to scale in the short run). These tasks are beyond the scope of our paper.

## B Data Appendix

### B.1 EU KLEMS accounting data

**Basic data** Our main data source is the December 2021 release of EU KLEMS (Bontadini *et al.* (2023), <https://euklems-intanprod-llee.luiss.it/>). KLEMS provides industry-level accounting data. Industries are classified according to the statistical classification of economic activities in the European Community (NACE, Revision 2).

We restrict our attention to the market economy, defined by KLEMS as including all industries except public administration and defence, social security, education, health and social work, household activities, activities of extraterritorial bodies, and real estate.<sup>41</sup> We further drop agriculture, forestry and fishing (NACE code A), mining and quarrying (NACE code B), and manufacturing of coke and refined petroleum products (NACE code C19). This leaves us with 25 industries in our baseline analysis, listed in Table A.1.<sup>42</sup>

Table A.1: Industry list for European countries (KLEMS, NACE Rev. 2)

<i>Non-durable manufacturing</i>	NACE Code
Food products, beverages and tobacco	C10-C12
Textiles, wearing apparel, leather and related products	C13-C15
Wood and paper products; printing and reproduction of recorded media	C16-C18
Chemicals and chemical products	C20
Basic pharmaceutical products and pharmaceutical preparations	C21
Rubber and plastics products, and other non-metallic mineral products	C22-C23
<i>Durable manufacturing</i>	NACE Code
Basic metals and fabricated metal products, exc. machinery and equipment	C24-C25
Computer, electronic and optical products	C26
Electrical equipment	C27
Machinery and equipment n.e.c.	C28
Transport equipment	C29-C30
Other manufacturing; repair and installation of machinery and equipment	C31-C33
<i>Non-manufacturing</i>	NACE Code
Electricity, gas, steam and air conditioning	D
Water supply, sewerage and waste management	E
Construction	F
Wholesale and retail trade; Repair of motor vehicles and motorcycles	G
Transportation and storage	H
Accommodation and food service activities	I
Publishing, Motion Picture, Recording and Broadcasting	J58-J60
Telecommunications	J61
Computer programming and information services	J62-J63
Financial and Insurance Activities	K
Professional, scientific, technical, administrative and support service activities	M-N
Arts, entertainment, and recreation	R
Other service activities	S

<sup>41</sup>As noted by O'Mahony and Timmer (2009), "for the most part the output of the real estate sector [...] is imputed rent on owner-occupied dwellings". This makes productivity measures hard to interpret.

<sup>42</sup>Note that Spain lumps together data for industries C20 and C21, and for industries C26 and C27.

We use six KLEMS time series from the KLEMS national accounts: nominal gross output (GO\_CP), the price index for gross output (GO\_PI), nominal expenditure on intermediate inputs (II\_CP), the price index for intermediate inputs (II\_PI), the total number of persons engaged (EMP), total hours worked by persons engaged (H\_EMP).<sup>43</sup> We also use three variables from the KLEMS growth accounts: the KLEMS index for capital input (CAP\_QI), the KLEMS index for labour input (LAB\_QI) and the nominal wage bill (LAB). Finally, we use three series from the KLEMS capital account: the nominal capital stock (K\_), the quantity index for capital input (Kq\_) and the price index for investment goods (Ip\_). These three series are provided separately for nine different assets, listed in Table A.2.<sup>44</sup> All series provide annual industry-level data.

Table A.2: Capital assets in KLEMS

KLEMS abbreviation	Variable
IT	Computing equipment
CT	Communications equipment
SOFT_DB	Computer software and databases
TraEq	Transport equipment
OMach	Other machinery and equipment
OCon	Non-residential investment (structures)
Cult	Cultivated assets
RD	Research & Development
OIPP	Other intellectual property products
GFCF	Gross Fixed Capital Formation (all assets)

Finally, we also use KLEMS data on depreciation rates for these nine assets (Adarov and Stehrer (2019), Stehrer *et al.* (2019)).<sup>45</sup> These depreciation rates are constant over time.

**Mapping KLEMS to our model** Table A.3 summarizes the mapping between KLEMS variables and our model.

This mapping is mostly straightforward. However, our treatment of the KLEMS indices for total labour and capital input, LAB\_QI and CAP\_QI, deserves some further discussion. The KLEMS index for total labour input, LAB\_QI, is an aggregate across 18 types of workers (differentiated by gender, three age groups and three education groups). KLEMS computes the growth rates of total hours worked at the level of each group, and then aggregates them compensation weights, i.e. the share of each group in the total wage bill of the industry. Thus, strictly speaking, this measure equals  $\frac{\bar{w}_t^V N_t^V}{\bar{w}_t^V N_t^V + \bar{w}_t^F N_t^F} (dN_t^V + dH_t^V) + \frac{\bar{w}_t^F N_t^F}{\bar{w}_t^V N_t^V + \bar{w}_t^F N_t^F} (dN_t^F + dH_t^F)$  in our model. This is not exactly equal to the contribution of total

<sup>43</sup>In Spain and in the UK, KLEMS does not provide a separate price index for gross output and intermediate inputs before the year 2000. Therefore, we compute real growth rates for these countries by using the price index for value added (VA\_PI).

<sup>44</sup>We exclude from the table the asset RStruc (Residential Structures), which has no observations outside of the real estate industry.

<sup>45</sup>As the 2021 release of KLEMS did not provide depreciation rates, we use the ones from the previous (2019) release. In general, KLEMS depreciation rates do not change much between releases.

hours worked to production, which in our model is instead given by  $\frac{\alpha_L^V}{\alpha_L^V + \alpha_L^F} (dN_t^V + dH_t^V) + \frac{\alpha_L^F}{\alpha_L^V + \alpha_L^F} (dN_t^F + dH_t^F)$ . However, as changes in the relative wage bill of the two categories of workers over time are small, we ignore this difference and use LAB\_QI to measure labour, allowing us to take advantage of the full level of detail available in the KLEMS database.

Table A.3: Correspondence between KLEMS variables and our model

Model variable	KLEMS variable
$dY_t$	$dGO\_CP_t - dGO\_PI_t$
$dM_t$	$dII\_CP_t - dII\_PI_t$
$\frac{\alpha_L^V}{\alpha_L^V + \alpha_L^F} (dN_t^V + dH_t^V) + \frac{\alpha_L^F}{\alpha_L^V + \alpha_L^F} (dN_t^F + dH_t^F)$	$dLAB\_QI_t$
$N_t^V + N_t^F$	$EMP_t$
$H_t^V N_t^V + H_t^F N_t^F$	$H\_EMP_t$
$P_{M,t} M_t$	$II\_CP_t$
$\tilde{w}_t^V N_t^V + \tilde{w}_t^F N_t^F$	$LAB_t$
$P_{L,t}^a K_t^a$	$K\_a_t$
$K_t^a$	$Kq\_a_t$
$P_{L,t}^a$	$Ip\_a_t$
$\delta_K^a$	$dpra_t$

On the other hand, we do not use the KLEMS index for total capital input, CAP\_QI, in our baseline analysis. The reason for this is that the way in which KLEMS computes this index assumes zero profits, and is thus inconsistent with our estimation method.

Precisely, the KLEMS CAP\_QI variable is a weighted average of the growth rate of the capital stocks for the nine different assets listed in Table A.2. The weights are given by the share of each asset in total capital compensation:

$$s_{K,t}^a = \frac{R_t^a P_{L,t-1}^a K_t^a}{\sum_{a'} R_t^{a'} P_{L,t-1}^{a'} K_t^{a'}}. \quad (\text{A.25})$$

where  $R_t^a$  is the rental rate of asset  $a$ . Then, KLEMS defines

$$dCAP\_QI_t = \sum_a \frac{1}{2} (s_{K,t-1}^a + s_{K,t}^a) dK_t^a \quad (\text{A.26})$$

To compute rental rates, KLEMS starts from the same Hall-Jorgenson equation as in our paper, evaluated separately for each asset  $a$ :

$$R_t^a = 1 + r_t - (1 - \delta_K^a) \frac{P_{L,t}^a}{P_{L,t-1}^a}. \quad (\text{A.27})$$

However, KLEMS computes the interest rate  $r_t$  as the return to capital in the industry, assuming zero profits (i.e., the return to an investor who buys the entire capital stock, and receives the difference between value added and labour payments as a dividend). This is

inconsistent with our estimation, which finds positive profits. Instead, we compute a rental rate for each asset by using equation (A.27) and our baseline interest rate. From this, we obtain the total cost for this asset,  $R_t^a P_{I,t-1}^a K_t^a$ . Total costs are then

$$\sum_{a=1}^A R_t^a P_{I,t-1}^a K_t^a + \text{LAB}_t + \text{II\_CP}_t. \quad (\text{A.28})$$

From this, we can easily compute the share of each production factor in total costs for every year  $t$ . Taking the average of these cost shares over time gives our estimates for the production function elasticities  $\alpha_K^a$ ,  $\alpha_L$  and  $\alpha_M$ .

Note that this approach to computing capital input is not crucial for our results. If we ignore the inconsistent aggregation and directly use the KLEMS CAP\_QI series (computing the cost share of capital using the aggregate capital stock, given by the KLEMS “asset” GFCF), our results are largely unchanged, as shown in Appendix C.2. For the BFK and Solow series, we use CAP\_QI throughout.

## B.2 Labour composition

To measure labour composition, we rely on microdata from the European Union Labour Force Survey (Eurostat (2022)).<sup>46</sup> The EU LFS provides industry-level annual data on employment and total hours by contract type (permanent or temporary) and job status (full-time or part-time).<sup>47</sup> We define quasi-fixed labour as the labour provided by workers with permanent and full-time contracts, and variable labour as the labour provided by all other workers. We then compute the employment and hours share of each of the two categories, and apply these to the KLEMS data on employment and hours worked to obtain a series in levels.

## B.3 Interest rates

For our baseline results, we use 10-year government bond rates from the OECD (2024b) to measure the risk-free interest rate.<sup>48</sup> We also use Moody’s Baa US bonds with a maturity of 20 years or more (from Moody’s (2024) as in Gutierrez (2018)) to measure the risk premium on bonds,<sup>49</sup> and equity risk premia from Datastream (London Stock Exchange Group (2022), series USASERP, ITASERP, ESASERP, FRASERP, UKASERP and BDASERP). Finally, we take debt-to-asset ratios from Tressel and de Almeida (2020), who compute these ratios for a sample of publicly traded firms in the year 2010.

For robustness checks, we also use corporate tax rates from the OECD (2024b), and Standard&Poor’s yields for BBB-rated corporate bonds with a 10-year maturity. We obtain

<sup>46</sup>See <https://ec.europa.eu/eurostat/web/microdata/european-union-labour-force-survey>.

<sup>47</sup>The LFS only provides information at the NACE 1-digit level. Thus, we need to assign the same employment and hours split to all industries belonging to a 1-digit NACE group.

<sup>48</sup>See <https://data.oecd.org/interest/long-term-interest-rates.htm>.

For some US missing years we use data from Board of Governors of the Federal Reserve System (2024).

<sup>49</sup>See <https://fred.stlouisfed.org/series/DBAA>.

these from Datastream (London Stock Exchange Group (2022), series SPEIB3E (Euro Area), SPUKI3B (UK) and UKSPUIG3B (US)).

## B.4 Capacity utilization surveys

Our data on capacity utilization comes from the Joint Harmonised EU Programme of Business and Consumer Surveys (European Commission (2024)). These surveys are harmonized at the EU level, but carried out separately in every member state by a national “partner institute” (generally, but not always, the National Statistical Office).<sup>50</sup>

All manufacturing data comes from the quarterly Industry survey, which asks firms “*At what capacity is your company currently operating (as a percentage of full capacity)?*” The firm then has to fill out the blank in the following sentence, “*The company is currently operating at \_\_ % of full capacity*”. Surveys are representative at the industry-level, and the sample size varies between 2’000 firms (in Spain) and 4’000 firms (in France and Italy). The firm-level data is aggregated to the industry-level by using employment weights.<sup>51</sup> We obtain an annual measure of capacity utilization by taking a simple average of the industry-level quarterly measures. The survey provides data for 24 NACE industries, which we aggregate to the 10 KLEMS manufacturing industries by using value added weights (Eurostat (2024e)).

Starting in 2011, the Services Sector survey also measures capacity utilization for service industries. Firms are asked “*If the demand addressed to your firm expanded, could you increase your volume of activity with your present resources? If so, by how much?*” The Commission interprets the hypothetical level of activity that a firm could reach as that firm’s full capacity output (Gayer (2013)). Capacity utilization is defined as the ratio of current output to full capacity output. As in the manufacturing sector, the industry-level data is a weighted average of the firm-level responses. We use data from this survey, whenever available, in our baseline analysis. To extend the series for years before 2011, we backcast industry-level series by projecting them on average capacity utilization in manufacturing.

Table A.4: Capacity utilization data availability in non-manufacturing industries

Country	Starting date	Non-manufacturing industries covered
Germany	2011 Q1	H, I, J62-J63, M-N
Spain	2011 Q3	H, I, J58-J60, J61, J62-J63, K, M-N, R, S
France	2011 Q4	H, I, J58-J60, J61, J62-J63, M-N, S
Italy	2010 Q3	H, I, J58-J60, J61, J62-J63, M-N, R, S
United Kingdom	2011 Q3	H, I, J58-J60, J62-J63, M-N, R

Table A.4 summarizes the data availability for the non-manufacturing sector. Note that Utilities (D-E), Construction (F) and Wholesale and Retail Trade (G) are not covered by

<sup>50</sup>See [https://ec.europa.eu/info/business-economy-euro/indicators-statistics/economic-databases/business-and-consumer-surveys\\_en](https://ec.europa.eu/info/business-economy-euro/indicators-statistics/economic-databases/business-and-consumer-surveys_en).

<sup>51</sup>More detailed information is available in the metadata sheets of the European Commission’s partner institutes, available at [https://ec.europa.eu/info/business-economy-euro/indicators-statistics/economic-databases/business-and-consumer-surveys/methodology-business-and-consumer-surveys/metadata-partner-institutes\\_en](https://ec.europa.eu/info/business-economy-euro/indicators-statistics/economic-databases/business-and-consumer-surveys/methodology-business-and-consumer-surveys/metadata-partner-institutes_en).

the survey. For Wholesale and Retail, we use the average capacity utilization in all service industries, and for Utilities and Construction, the manufacturing average. Our results are unchanged when using the services average instead for these latter industries.

## B.5 US data

**Growth accounting** Our main data source for the United States is the TFP database of the BLS (Bureau of Labor Statistics (2022b)), available at <https://www.bls.gov/productivity/tables/home.htm>). This database provides industry-level growth accounting data that is comparable to KLEMS. Industries are classified according to the North American Industry Classification System (NAICS). Just as in Europe, we focus on the market economy and exclude agriculture (NAICS Code 11), mining (21), Petroleum and Coal (324), Real Estate (531), Educational Services (61), Health Care and Social Assistance (62) as well as Public Administration (92). As the BLS dataset is more disaggregated than EU KLEMS, we have data for a total of 49 industries, listed in Table A.5.

Table A.5: Industry list for the United States (NAICS)

<i>Non-durable manufacturing</i>	NAICS Code
Food and beverage and tobacco products	311-312
Textile mills and textile product mills	313-314
Apparel and leather and allied products	315-316
Paper products	322
Printing and related support activities	323
Chemical products	325
Plastics and rubber products	326
<i>Durable manufacturing</i>	NAICS Code
Wood products	321
Nonmetallic mineral products	327
Primary metals	331
Fabricated metal products	332
Machinery	333
Computer and Electronic products	334
Electrical Equipment, Appliances, and Components	335
Motor vehicles, bodies and trailers, and parts	3361-3363
Other transportation equipment	3364-3369
Furniture and related products	337
Miscellaneous manufacturing	339
<i>Non-manufacturing</i>	NAICS Code
Utilities	22
Construction	23
Wholesale Trade	42
Retail Trade	44-45
Air transportation	481
Rail transportation	482
Water transportation	483
Truck transportation	484
Transit and ground passenger transportation	485
Pipeline transportation	486
Other transportation and support activities	487, 488, 492
Warehousing and Storage	493

Continuation of Table A.5

Publishing industries, except internet (includes software)	511
Motion picture and sound recording industries	512
Broadcasting and telecommunications	515, 517
Data processing, internet publishing, and other information services	518-519
Monetary authorities, credit intermediation and related activities	521-522
Securities, commodity contracts, other fin. inv. and related activities	523
Insurance Carriers and Related Activities	524
Funds, Trusts, and Other Financial Vehicles	525
Rental and leasing services and lessors of intangible assets	532-533
Legal services	5411
Computer systems design and related services	5415
Miscellaneous professional, scientific, and technical services	5412-5414, 5416-5419
Management of companies and enterprises	55
Administrative and support services	561
Waste management and remediation services	562
Performing arts, spectator sports, museums, and related activities	711-712
Amusements, gambling, and recreation industries	713
Accommodation	721
Food services and drinking places	722

The BLS database contains the same series as EU KLEMS, with the exception of employment and hours worked (instead, the BLS only provides a measure of total labour input, the equivalent of the KLEMS LAB\_QI variable). Thus, we obtain series for employment and hours worked from the BLS Labor Productivity and Costs (LPC) database (available at <https://www.bls.gov/lpc/home.htm>). Finally, we obtain capital data (on investment good prices, depreciation rates, nominal and real capital stocks) from the BLS Capital Details tables.

The BLS uses five capital assets: land, inventories, intellectual property products, equipment and structures. The BLS database follows similar conventions than EU KLEMS, and we can therefore easily map its variables into KLEMS codes, as shown in Table A.6.

Table A.6: Correspondence between BLS and KLEMS variables

BLS variable	BLS dataset	KLEMS variable
Value of Production	TFP	GO_CP
Price of Sectoral Output	TFP	GO_PI
Cost of Intermediate Inputs	TFP	II_CP
Price of Intermediate Input	TFP	II_PI
Cost of Labor	TFP	LAB
Capital input	TFP	CAP_QI
Labor input	TFP	LAB_QI
Employment	LPC	EMP
Hours worked	LPC	H_EMP
Capital price deflator	TFP (Capital details)	Ip_a
Productive Capital stock	TFP (Capital details)	Kq_a
Wealth stock depreciation rate	TFP (Capital details)	dpr_a

It is worth noting that BLS definitions sometimes differ from KLEMS definitions (see Jäger (2018)). For instance, both datasets differ in their choices for considering certain

expenses as intermediate inputs or capital investment. This can account for some differences in the capital series between both datasets. One notable difference is the fact that the BLS accounts for land and inventories as capital assets, while KLEMS does not. This might lead to an overestimation of profit shares in Europe. We explore this concern in Appendix C.3.

In the US, there is no direct equivalent to the European notion of permanent and temporary employment contracts. Therefore, we define quasi-fixed labour as labour provided by workers with full-time contracts, and variable labour as labour provided by workers with part-time contracts. We obtain time series on employment and hours for these two types of workers from unpublished occupation and industry tables from the Current Population Survey (CPS), kindly provided to us by the [Bureau of Labor Statistics \(2022a\)](#).<sup>52</sup>

**Capacity utilization** US capacity utilization data comes from the Federal Reserve Board’s monthly reports on Industrial Production and Capacity Utilization (G.17) ([Federal Reserve Board \(2024\)](#)).<sup>53</sup>

The data is constructed by the Federal Reserve on the basis of the Census Bureau’s Quarterly Survey of Plant Capacity (QSPC) and other information sources.<sup>54</sup> The QSPC is carried out at the plant level. Plants are first asked to report the value of current production. Second, they should report their full production capacity, defined as “*the maximum level of production that this establishment could reasonably expect to attain under normal and realistic operating conditions fully utilizing the machinery and equipment in place*”. In the detailed instructions that plant managers are given, it is noteworthy that the Census suggests that “*if you have a reliable or accurate estimate of your plant’s sustainable capacity utilization rate, divide your market value of production at actual operations [...] by your current rate of capacity utilization [to get full production capacity]*”. Finally, plants are asked to report the ratio between current and full production, which is capacity utilization. Plant-level estimates are aggregated to the industry-level by using full capacity production weights. For our purposes, we use the annual version of the Federal Reserve’s database, which provides data for 17 NAICS manufacturing industries, as well as for Electric and Gas utilities.

The US does not have a survey on capacity utilization in services. Therefore, we use average capacity utilization in manufacturing as a utilization proxy for all non-manufacturing industries (with the exception of utilities).

## B.6 Instruments

**Oil shocks** Data on nominal oil prices are from the [World Bank \(2024\)](#) (Commodity Price Data, The Pink Sheet) and from the [FRED \(2024\)](#), and deflated with country-specific CPIs from [OECD \(2024a\)](#). Following [Basu et al. \(2006\)](#), we compute oil price shocks as the

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<sup>52</sup>The split of employment and hours is not available before 1994. For these years, we assume that growth in employment and hours per worker for both categories is equal to growth in overall employment or overall hours per worker. This has only a very limited impact on our results, as this data is only used in Appendix D.4.

<sup>53</sup>The data can be accessed at <https://www.federalreserve.gov/releases/G17/Current/default.htm>.

<sup>54</sup>An overview of the Federal Reserve’s methodology is available at <https://www.federalreserve.gov/releases/g17/CapNotes.htm>.

log difference between the current quarterly real oil price and the highest real oil price in the preceding four quarters. We define the annual oil price shock as the sum of the four quarterly shocks.

**Monetary policy shocks** For Euro Area countries and for the US, we take monetary policy shocks from [Jarociński and Karadi \(2020\)](#), who rely on surprise movements in interest rates and stock markets after ECB and Federal Reserve policy announcements to identify monetary policy shocks at the monthly frequency. We take simple averages of these shocks to obtain an annual series. For the UK, we follow [Cesa-Bianchi \*et al.\* \(2020\)](#), who identify monetary policy shocks through changes in the price of 3-month Sterling future contracts after policy announcements by the Bank of England.<sup>55</sup>

**Financial shocks** We measure financial shocks by using the excess bond premium introduced by [Gilchrist and Zakrajšek \(2012\)](#).<sup>56</sup> This measure is the difference between the actual spread of unsecured bonds of US firms and the predicted spread based on firm-specific default risk and bond characteristics. Thus, it captures variation in the average price of US corporate credit risk, above and beyond the compensation for expected defaults. We aggregate the monthly excess bond premium to its annual average to obtain our shocks.

**Uncertainty shocks** Our measure of Economic Policy Uncertainty (EPU) was developed by [Baker \*et al.\* \(2016\)](#), and is regularly updated at <http://www.policyuncertainty.com>. For European countries, the measure is a monthly index based on newspaper articles on policy uncertainty (articles containing the terms uncertain or uncertainty, economic or economy, and one or more policy-relevant terms). The number of economic uncertainty articles is then normalized by a measure of the number of articles in the same newspaper and month, and the resulting newspaper-level monthly series is standardized to unit standard deviation prior to 2011. Finally, the country-level EPU series is obtained as the simple average of the series for the country's newspapers, and normalized to have a mean of 100 prior to 2011.<sup>57</sup> For the US, measurement is more sophisticated, considering not only newspaper articles, but also the number of federal tax code provisions set to expire in future years and disagreement among economic forecasters.

In order to obtain an annual series, we take a simple average of monthly values. For country-years with missing data (before 1997 for Italy and the UK, and before 2001 for Spain), we use the simple average of the series for the other European countries.

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<sup>55</sup>For all cited papers, the authors provide this data in their replication files. Updated files are available at <https://marekjarocinski.github.io/> and <https://sites.google.com/site/ambropo/publications>. Ambrogio Cesa-Bianchi also kindly shared an extended series with us.

<sup>56</sup>Data is available at <https://www.federalreserve.gov/econresdata/notes/feds-notes/2016/updating-the-recession-risk-and-the-excess-bond-premium-20161006.html>.

<sup>57</sup>The newspapers used are Le Monde and Le Figaro for France, Handelsblatt and Frankfurter Allgemeine Zeitung for Germany, Corriere Della Sera and La Repubblica for Italy, and El Mundo and El Pais for Spain.

## B.7 Input-Output tables

For European countries, we obtain country-specific input-output tables from the FIGARO tables of Eurostat (2024a).<sup>58</sup> We use tables for the year 2010, and drop all transactions with foreign countries and industries not covered in our sample. For the US, we rely on the Bureau of Economic Analysis (2024) “Use” tables.<sup>59</sup> Likewise, we drop all transactions with industries not covered by our sample.

## B.8 Recession definitions

Recession dates are taken from the National Bureau of Economic Research (2024) for the US, the Euro Area Business Cycle Network (2024) for the Euro Area, and the Office for National Statistics (2024) for the UK.

## B.9 Plots of key variables

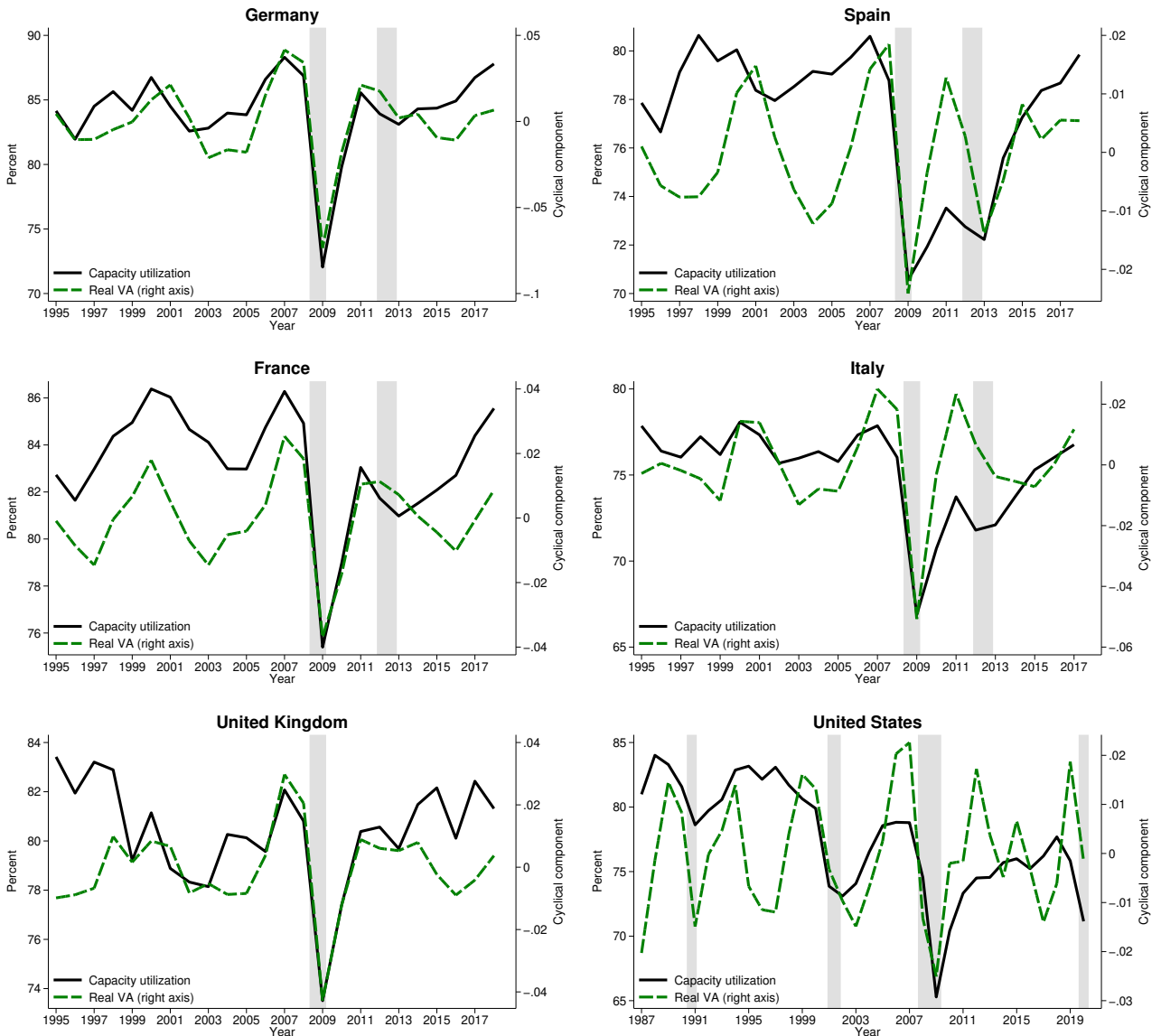
Figures A.1 to A.5 summarize the behaviour of some of the key variables.

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<sup>58</sup>See <https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/data/database>.

<sup>59</sup>See <https://www.bea.gov/industry/input-output-accounts-data>.

Figure A.1: Capacity utilization in the manufacturing sector



**Notes:** This figure plots average capacity utilization in manufacturing against the cyclical component of aggregate real value added (filtered with a band-pass filter). Data sources are described in Section 3. Shaded areas mark recessions, defined in Appendix B.8.

Figure A.1 plots average capacity utilization in manufacturing against the cyclical component of real value added (filtered with a band-pass filter). The remaining figures plot output and input growth across the three broad sectors used in our analysis. To generate these plots, we aggregate real gross output, real spending on materials and employment across the three sectors covered by our analysis. For capital, instead, we take value-added weighted averages of our measure of growth in capital inputs. These graphs clearly show that capital is much less volatile than other inputs. This is a key mechanism driving the profit adjustment in our estimated TFP series.

Figure A.2: Gross output growth

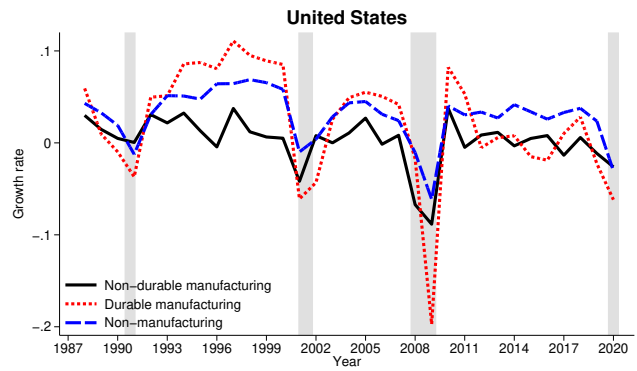
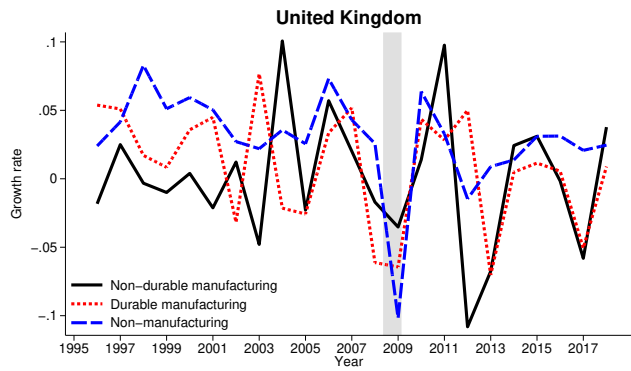
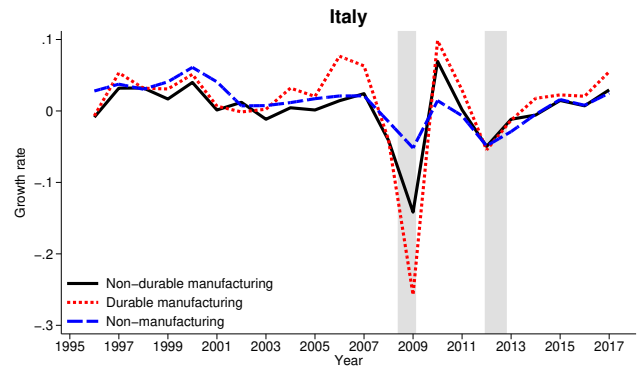
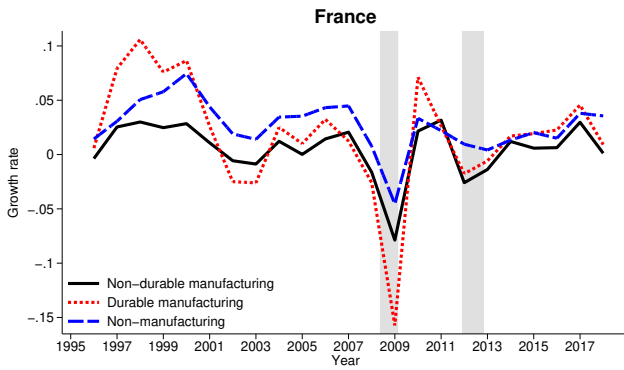
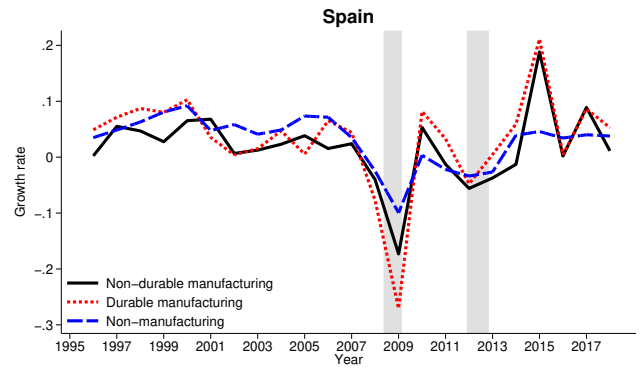
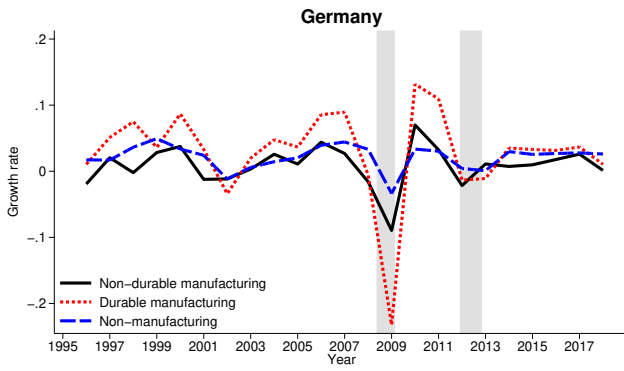


Figure A.3: Material input growth

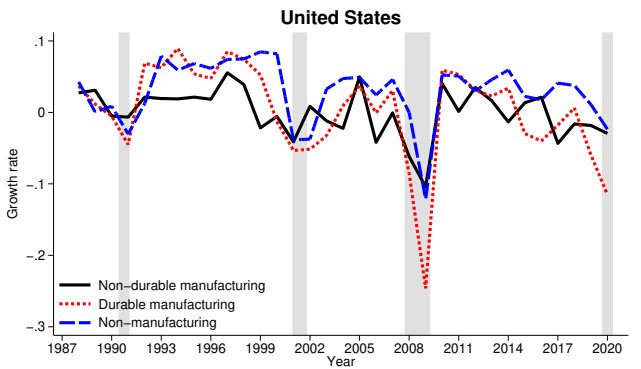
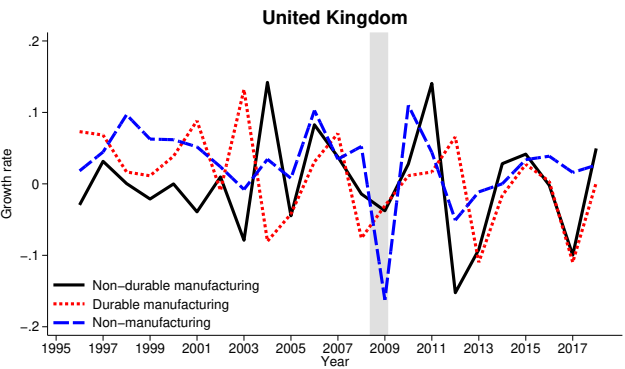
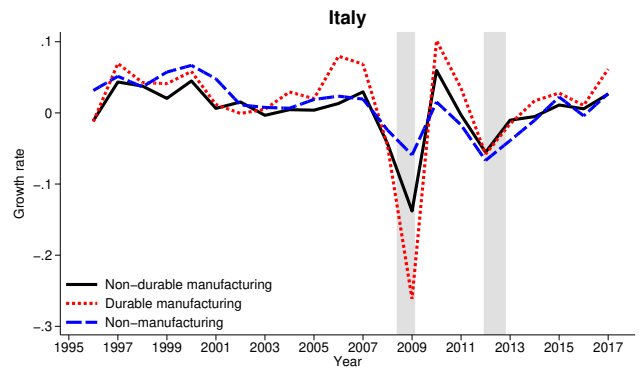
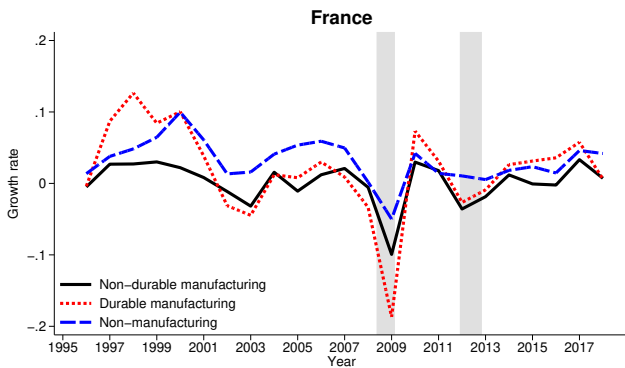
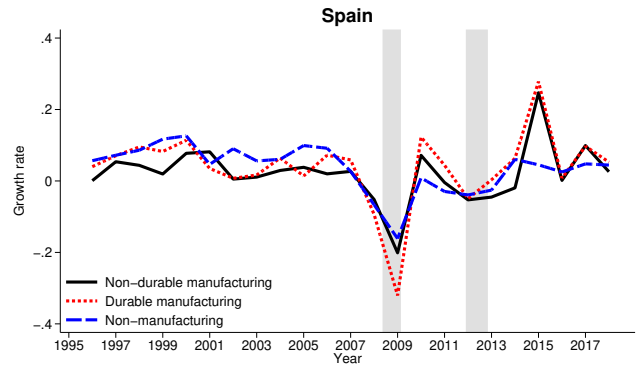
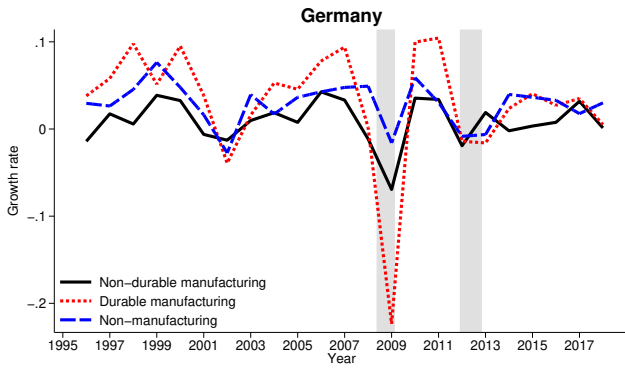


Figure A.4: Capital input growth

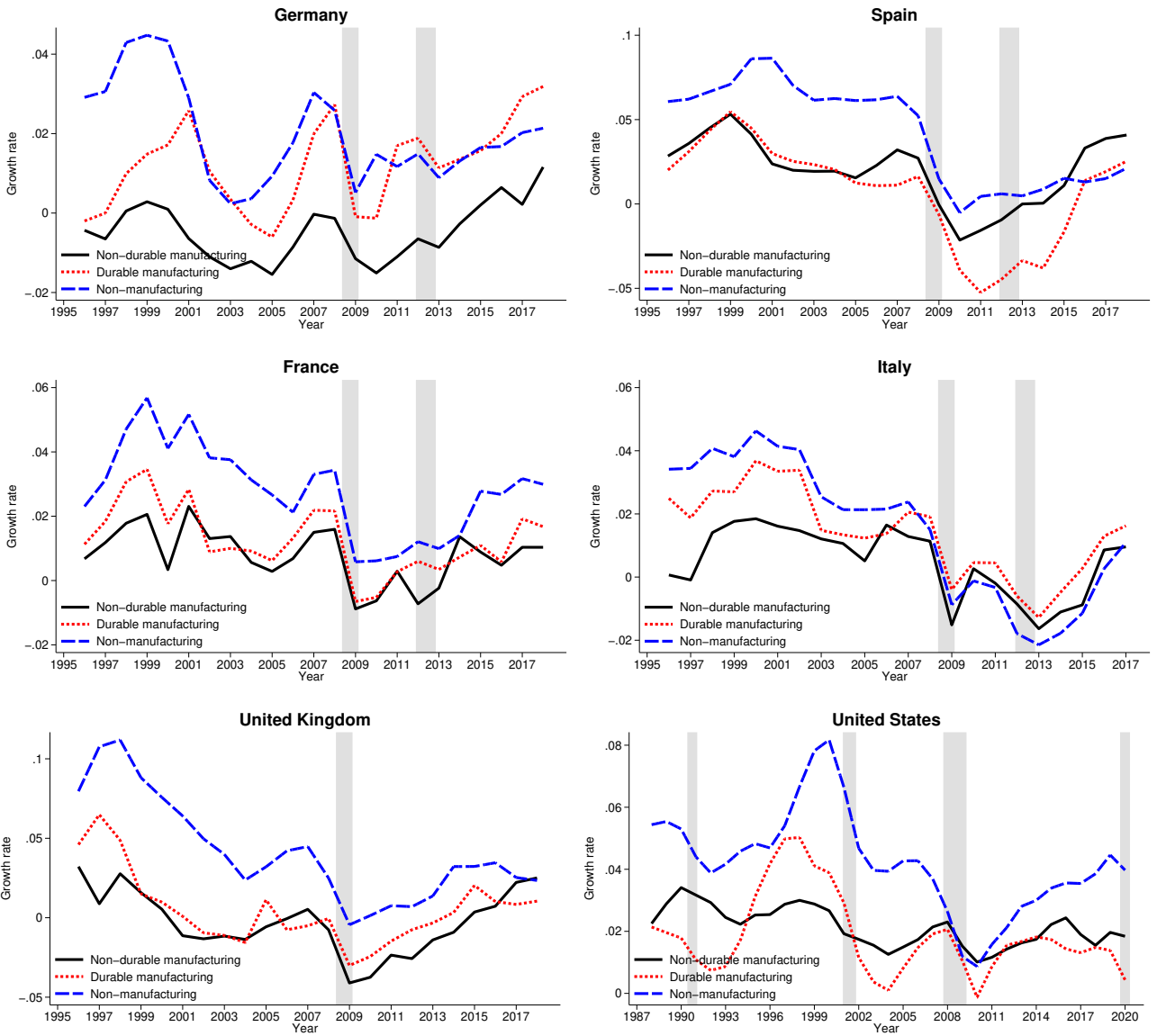
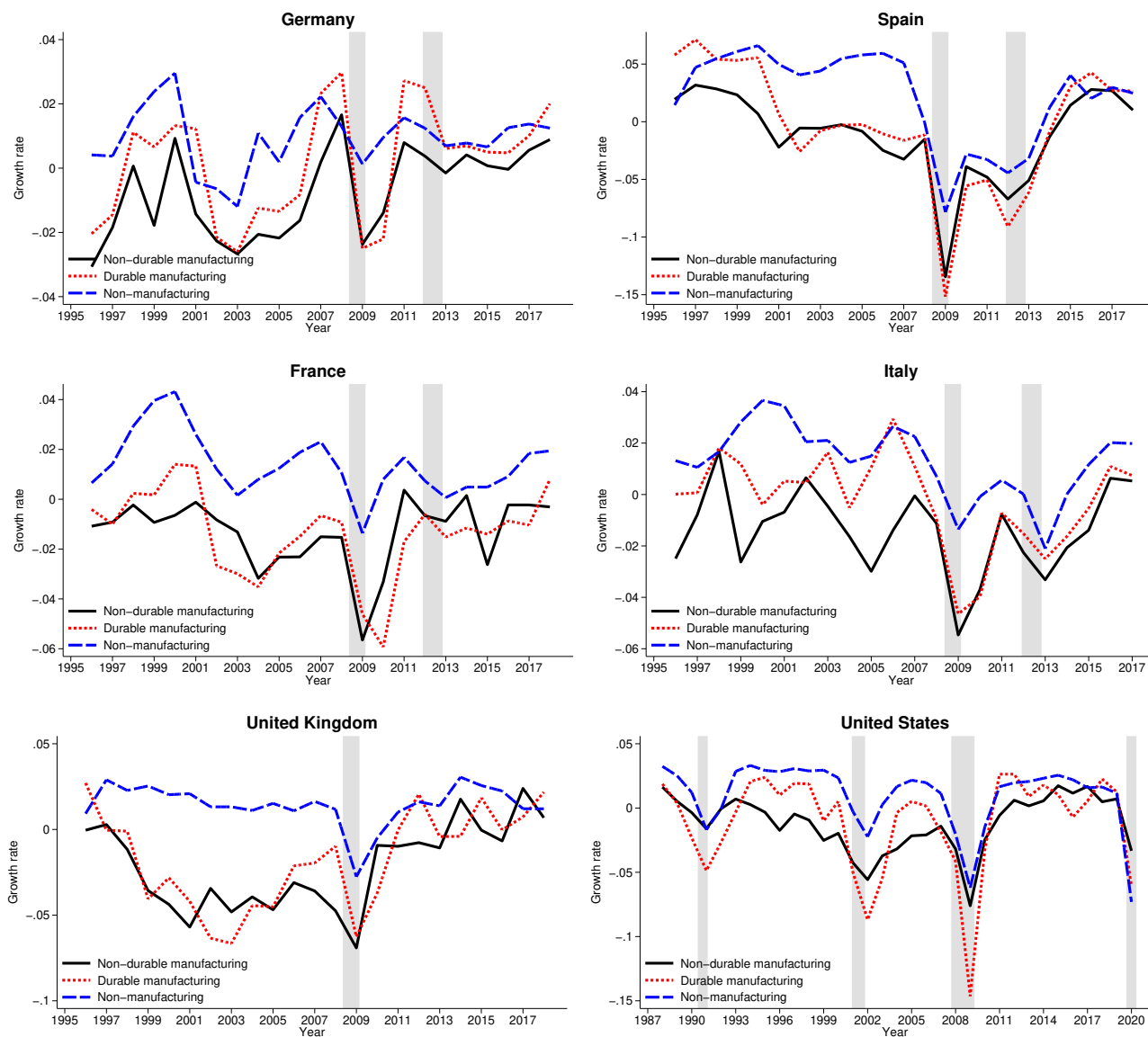


Figure A.5: Employment growth



## B.10 Quarterly data

We construct quarterly measures of output and input growth by using data from Eurostat. Eurostat’s database is also the main data source for EU KLEMS, and in the construction of our quarterly variables, we aim to follow KLEMS practice as closely as possible.<sup>60</sup>

One important deviation from KLEMS is the fact that there is no quarterly data on GDP, investment or employment per industry. Thus, we cannot focus on the same subset of industries as in our annual analysis. To keep our focus on business GDP, however, we adjust the quarterly series for all our variables by multiplying them with the share of the private

<sup>60</sup>In a previous version of our paper (Comin *et al.* (2023)), we also constructed a quarterly series for the US.

sector for the same variable at the annual frequency, taken from EU KLEMS.

**Output** We measure output growth as the growth of quarterly real GDP, taken from Eurostat (2024c)’s quarterly national accounts database. The data is seasonally adjusted and expressed in chain-linked volumes.

**Labour input** Our measure of labour input accounts for labour composition, in the spirit of the EU KLEMS LAB\_QI variable. Precisely, we use data on six different groups of workers, splitting the population of workers by gender and three age groups. For each of these groups, the EU Labour Force Survey provides quarterly data for employment and actual hours worked per week (Eurostat (2024b)). Data is available from the first quarter of 1998 for Italy and Spain, from the first quarter of 2003 for France, and from the first quarter of 2005 for Germany. These series are not seasonally adjusted, but display strong seasonal patterns. Therefore, we seasonally adjust each employment and hours per worker series by using the X-13ARIMA-SEATS algorithm. We then construct quarterly data between 1998 and 2003 for France and between 1998 and 2005 for Germany by linear interpolation of the available annual data.<sup>61</sup>

Finally, we construct an aggregate measure of labour input as

$$dH_t + dN_t = \sum_{d=1}^6 w_t^d (dH_t^d + dN_t^d), \quad (\text{A.29})$$

where  $dH_t^d$  is the growth rate of hours per worker for category  $d$  and  $dN_t^d$  is the growth rate of employment for category  $d$ . The different categories are weighted by their shares in total labour compensation,  $w_t^d$ . We compute these shares by using data from the EU Structure of Earnings Survey (Eurostat (2024f)). This survey is available every four years, starting in 2002, and we linearly interpolate values for the weights in all periods with missing data.

**Capital input** To construct a measure of capital input, we use data on real investment (gross fixed capital formation, seasonally adjusted and in chain-linked volumes) from Eurostat (2024d)’s quarterly national accounts database. Investment data is available from the first quarter of 1998. We combine this data with the 1998 value of the real capital stock in EU KLEMS and the implicit KLEMS depreciation rate to compute a value for the capital stock using the perpetual inventory method.<sup>62</sup>

We compute growth in capital inputs as the growth in this capital stock. This differs from our approach with the annual data, where we compute a weighted average of the growth rates of different capital asset stocks. However, there is not enough disaggregated data on investment in different asset classes in order to do the same at a quarterly frequency.

<sup>61</sup>We also correct two anomalies in the Italian data for hours per worker (in 2002Q2 and 2003Q1) through linear interpolation for these two quarters.

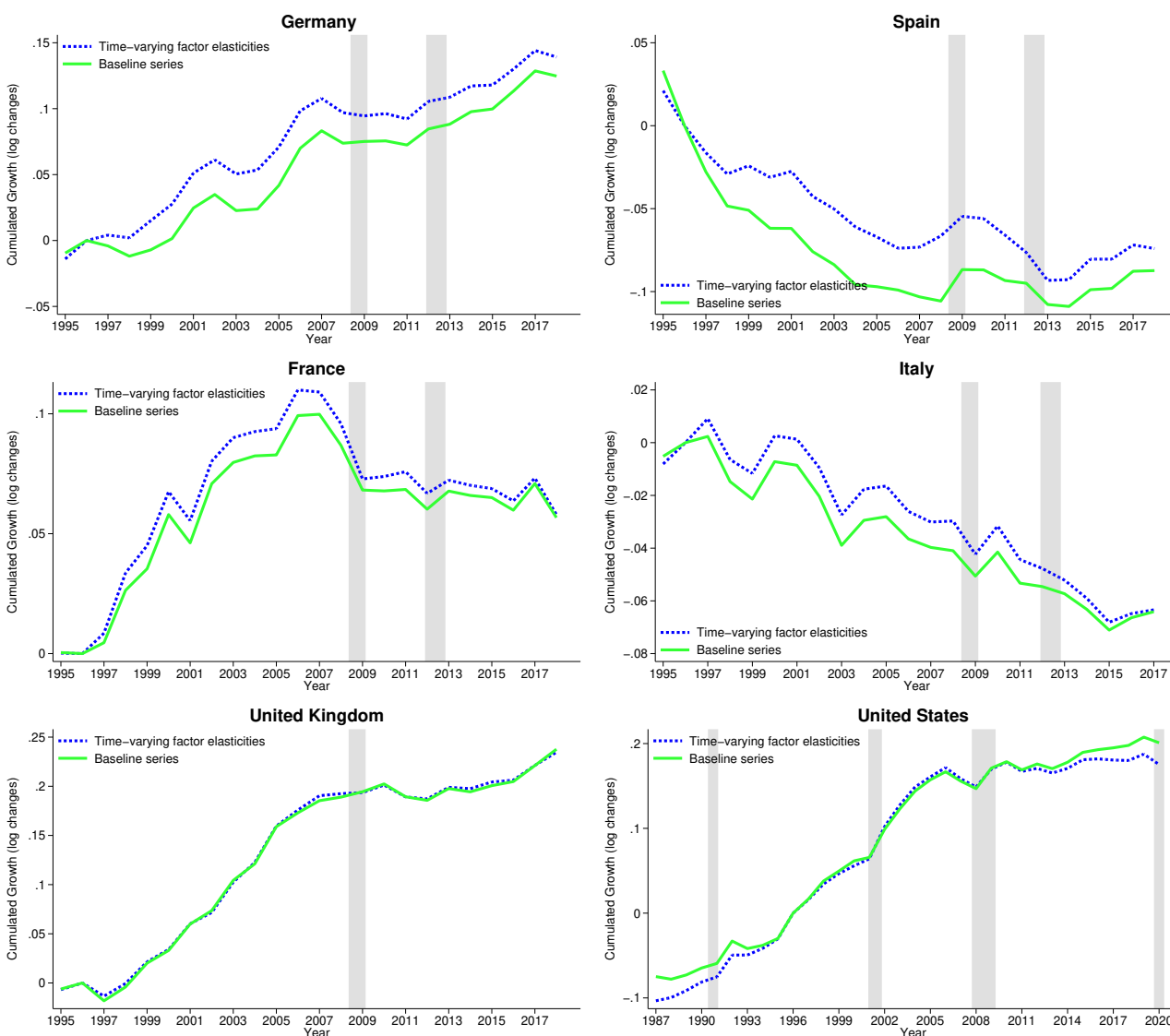
<sup>62</sup>EU KLEMS provides us with annual time series on the aggregate real capital stock  $K_t$  and investment  $I_t$ . We then compute an implicit annual depreciation rate as  $1 - \delta_{K,t} = \frac{K_{t+1} - I_t}{K_t}$ . We deduce from this the quarterly depreciation rate and use it to compute a quarterly capital stock series.

# C Robustness checks

## C.1 Time-varying output elasticities

Our baseline analysis assumes that output elasticities are constant over time. This assumption could be problematic in the presence of structural changes in production technologies which increase the importance of certain factors and decrease the importance of others. Therefore, this section considers a robustness check allowing for time variation in output elasticities.

Figure A.6: TFP growth with time-varying factor elasticities



**Notes:** This figure compares our baseline series for TFP growth with an alternative series that allows for time variation in factor elasticities. Shaded areas mark recessions, defined in Appendix B.8.

Precisely, we compute the elasticity of output with respect to a certain factor  $X$  as the

average between the current and last year’s cost shares (following the common practice in the KLEMS and BLS databases):

$$\alpha_{X,t} = \frac{cs_{X,t} + cs_{X,t-1}}{2}, \quad (\text{A.30})$$

where  $cs_{X,t}$  is the cost share of factor  $X$  in year  $t$ . Using these time-varying elasticities in equation (21), we conduct the same analysis as in the baseline.

Figure A.6 plots the series obtained with these time-varying elasticities against our baseline estimates for aggregate TFP growth. While there are certainly differences between series in several countries (especially in Germany and Spain), the overall patterns of TFP growth both in the short and in the long run do not change.

## C.2 Capital input aggregation

In our baseline analysis, we compute capital input as a weighted average of the growth rates of different assets. While this is consistent with our assumptions on profits, one might be concerned that the KLEMS capital input index, CAP\_QI, contains further adjustments that we would miss by dropping this variable.

To address this issue, Figure A.7 plots our estimates for TFP growth when we use CAP\_QI as our measure of growth in capital inputs. As the figure shows, doing so does not change the cyclical property of our TFP series. It does affect long-run productivity growth somewhat, with the strongest effects in Spain. Here, our disaggregated estimates of capital growth are higher than the growth in the KLEMS CAP\_QI index (by about 0.3 percentage points per year on average), and hence TFP growth is lower with the disaggregated measure.

## C.3 Land and inventories

One potential concern about capital measures in EU KLEMS is the fact that they do not include land and inventories (which are, in turn, included in BLS data for the US). This might lead us to underestimate capital costs, and hence to overestimate profits.

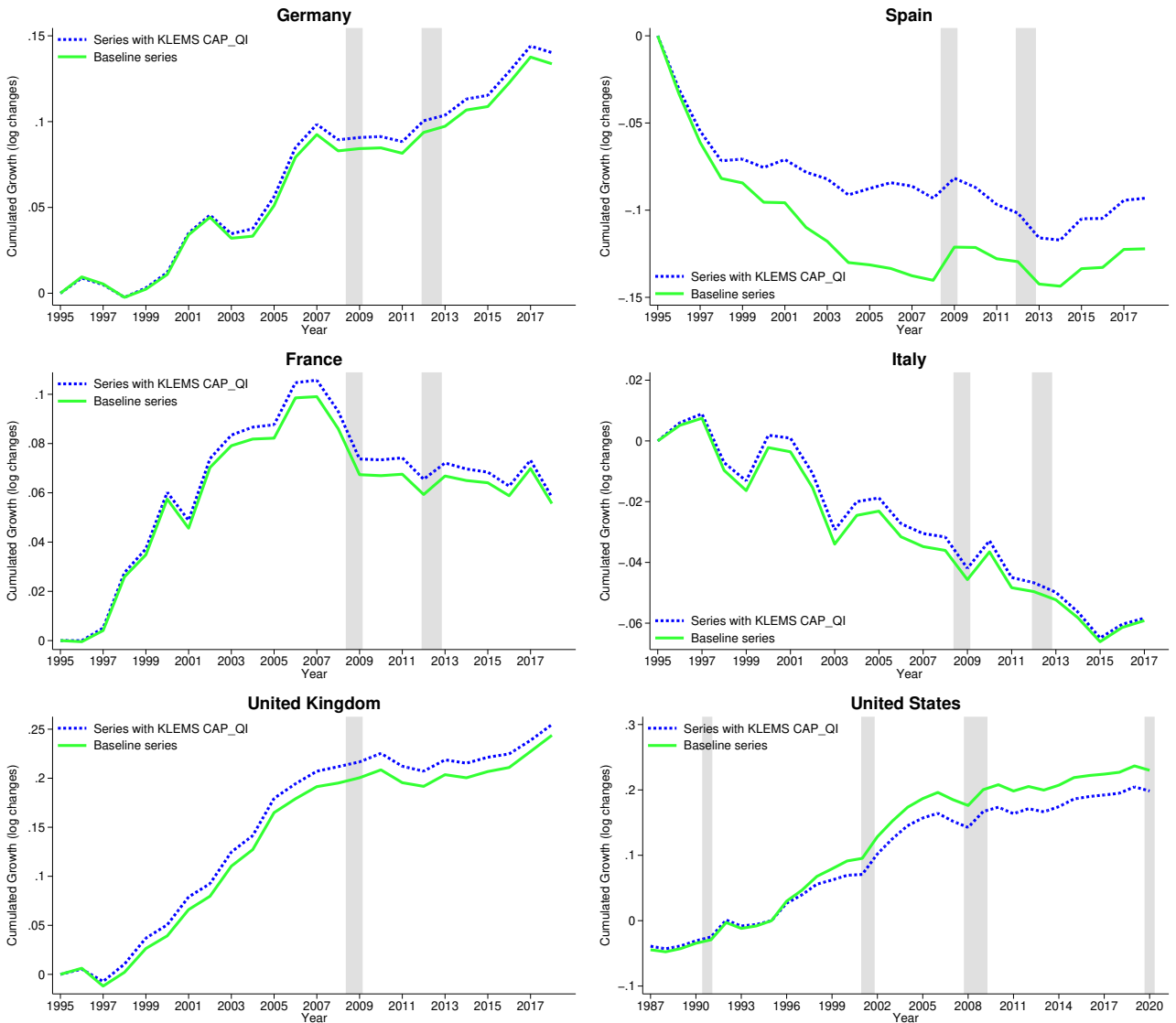
To address this issue, we apply a simple correction to our estimates for total capital costs. In our US data, land and inventories represent 9.6% of total capital costs. Therefore, we inflate capital costs for European countries by a factor  $1/1-0.096$ , which amounts to assuming that land and inventories command the same share of capital costs in Europe than in the US. This is likely to be a conservative assumption, as EU KLEMS does include “land improvements” and at least a share of land under buildings.<sup>63</sup>

Figure A.8 compares the TFP growth estimates obtained with these inflated capital cost shares to our baseline estimates. Higher capital costs imply lower profits, and hence they weaken the profit adjustment of our baseline series. However, as the figure shows, this effect is small.

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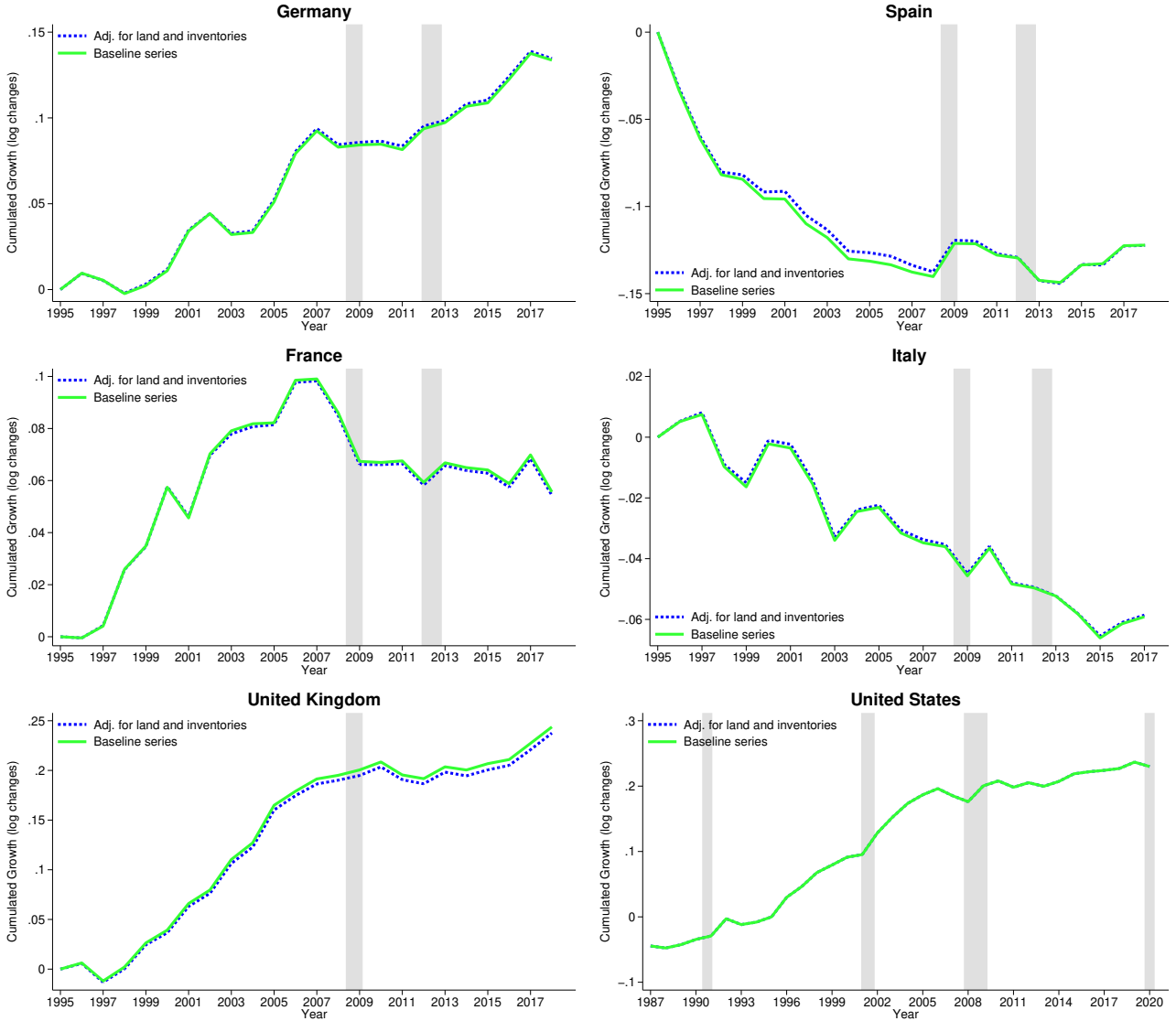
<sup>63</sup>For instance, national accounting guidelines state that “in case that it is not possible to separate the land from the related assets (buildings and other structures, water resources, mineral and energy resources, cultivated and non cultivated biological resources), SNA 2008 and ESA 2010 recommend to register the combined value under the more valuable asset” (SNA 2008 paragraph 13.46, ESA 2010 paragraph 7.52).

Figure A.7: Results for the KLEMS CAP\_QI capital input series



**Notes:** This figure plots our baseline measure of TFP growth against an alternative measure that uses the KLEMS CAP\_QI series as a measure of capital input. Shaded areas mark recessions, defined in Appendix B.8.

Figure A.8: Adjusting European capital costs for land and inventories



**Notes:** This figure plots our baseline measure of TFP growth against an alternative that inflates European capital costs to account for land and inventories. Shaded areas mark recessions, defined in Appendix B.8.

### C.4 Further robustness checks

In this section, we summarize the results of a series of further robustness checks. Tables A.7 to A.12 show the results of these checks for every country in our sample.

The first three robustness checks deal with the interest rate used to compute the rental rate of capital. In our baseline results, this interest rate is the sum of a country-specific risk-free interest rate and a weighted average of the risk premium on bonds and equity, as defined in equation (20). Here, we consider three alternatives. Robustness check (1) ignores equity and computes the interest rate as

$$1 + r_t^c = \text{GovBondYield}_t^c + \text{BaaSpread}_t, \tag{A.31}$$

where, as in the baseline,  $\text{GovBondYield}_t^c$  is the interest rate on 10-year government bonds of country  $c$ , and  $\text{BaaSpread}_t$  is the spread on Moody's Baa bonds with a maturity of 20 years or more.

In robustness check (2), we instead use country-specific bond yields, for Standard&Poor's BBB rates bonds with a maturity of 10 years. That is, we define the interest rate as

$$1 + r_t^c = \frac{D^c}{D^c + E^c} \cdot \text{BBBYield}_t^c + \frac{E^c}{D^c + E^c} \cdot (\text{GovBondYield}_t^c + \text{ERP}_t^c). \quad (\text{A.32})$$

In contrast to the baseline, this interest rate uses a country-specific bond risk premium. However, data for the BBB yield is only available after the year 2000, so that we can only compute profit shares for a shorter time horizon.

Finally, for robustness check (3), we take into account the fact that debt repayments can be deducted from taxes, and compute the interest rate as

$$1 + r_t^c = \frac{D^c}{D^c + E^c} \cdot (\text{GovBondYield}_t^c + \text{BaaSpread}_t) \cdot (1 - \tau^c) + \frac{E^c}{D^c + E^c} \cdot (\text{GovBondYield}_t^c + \text{ERP}_t^c), \quad (\text{A.33})$$

where  $\tau^c$  is the corporate tax rate in country  $c$ , taken from OECD.Stat.

As tables A.7 to A.12 show, using any of these three interest rates barely changes the cyclical behaviour of our TFP series: correlations with the baseline series are very close to 1, and correlations with the BFK TFP series and Solow residuals hardly change. Different interest rates do yield somewhat different levels of TFP growth, depending on whether they imply higher or lower profits than the baseline interest rate.

In robustness check (4), we assume that firms cannot make negative profits. That is, we set all negative BGP profit shares to zero. As there are few such industries, the impact of this change is limited.

In robustness checks (5), (6) and (7), we vary the set of instruments used in our utilization adjustment regressions. In robustness check (5), we drop the monetary policy shock, and in robustness check (6), we drop the uncertainty shock. In robustness check (7), in turn, we do not backcast missing values for the monetary policy shock. All of these changes have a negligible effect on our results.

In robustness check (8), we consider a different backcasting method for capacity utilization data in European non-manufacturing industries. In the baseline analysis, backcasting was based on a pooled regression across all non-manufacturing industries (as shown in the main text). Here, we instead run the backcasting regression industry by industry. Again, this does not affect our results.

Table A.7: Robustness checks, Germany

	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean TFP growth	0.58	0.56	0.50	0.57	0.58	0.59	0.58	0.58	0.58
Relative standard dev.	0.33	0.33	0.34	0.33	0.33	0.33	0.33	0.33	0.33
Corr. with real VA growth	0.23	0.23	0.20	0.23	0.23	0.33	0.23	0.27	0.25
<i>Corr. between TFP series</i>									
Baseline	.	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00
Solow residual	0.39	0.39	0.35	0.38	0.39	0.48	0.38	0.42	0.40
BFK method	0.74	0.75	0.73	0.74	0.75	0.79	0.71	0.76	0.75

**Notes:** Each numbered column corresponds to a different robustness check. Robustness check (1) uses an interest rate without equity, (2) uses an interest rate with Standard and Poor's country-specific bond yields, (3) uses an interest rate including taxes, (4) assumes that profits cannot be negative, (5) drops the monetary policy instrument, (6) drops the uncertainty instrument, (7) uses no backcasting for instruments, and (8) backcasts non-manufacturing utilization data using industry-level regressions.

Table A.8: Robustness checks, Spain

	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean TFP growth	-0.53	-0.54	-0.67	-0.54	-0.53	-0.53	-0.53	-0.53	-0.53
Relative standard dev.	0.39	0.40	0.42	0.40	0.39	0.40	0.39	0.39	0.40
Corr. with real VA growth	-0.22	-0.26	-0.30	-0.25	-0.23	-0.23	-0.21	-0.21	-0.22
<i>Corr. between TFP series</i>									
Baseline	.	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Solow residual	0.52	0.50	0.47	0.50	0.53	0.50	0.53	0.53	0.51
BFK method	0.56	0.54	0.51	0.54	0.57	0.53	0.57	0.56	0.55

**Notes:** Each numbered column corresponds to a different robustness check. Robustness check (1) uses an interest rate without equity, (2) uses an interest rate with Standard and Poor's country-specific bond yields, (3) uses an interest rate including taxes, (4) assumes that profits cannot be negative, (5) drops the monetary policy instrument, (6) drops the uncertainty instrument, (7) uses no backcasting for instruments, and (8) backcasts non-manufacturing utilization data using industry-level regressions.

Table A.9: Robustness checks, France

	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean TFP growth	0.24	0.24	0.19	0.24	0.24	0.23	0.24	0.24	0.24
Relative standard dev.	0.58	0.58	0.58	0.58	0.58	0.56	0.58	0.59	0.57
Corr. with real VA growth	0.60	0.59	0.59	0.60	0.60	0.49	0.61	0.62	0.58
<i>Corr. between TFP series</i>									
Baseline	.	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00
Solow residual	0.90	0.89	0.88	0.89	0.90	0.82	0.90	0.91	0.88
BFK method	0.83	0.82	0.82	0.83	0.83	0.82	0.83	0.85	0.83

**Notes:** Each numbered column corresponds to a different robustness check. Robustness check (1) uses an interest rate without equity, (2) uses an interest rate with Standard and Poor's country-specific bond yields, (3) uses an interest rate including taxes, (4) assumes that profits cannot be negative, (5) drops the monetary policy instrument, (6) drops the uncertainty instrument, (7) uses no backcasting for instruments, and (8) backcasts non-manufacturing utilization data using industry-level regressions.

Table A.10: Robustness checks, Italy

	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean TFP growth	-0.27	-0.27	-0.31	-0.27	-0.27	-0.28	-0.27	-0.27	-0.27
Relative standard dev.	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Corr. with real VA growth	0.39	0.38	0.36	0.38	0.39	0.17	0.33	0.35	0.36
<i>Corr. between TFP series</i>									
Baseline	.	1.00	1.00	1.00	1.00	0.96	1.00	1.00	1.00
Solow residual	0.60	0.60	0.59	0.60	0.61	0.37	0.55	0.56	0.58
BFK method	0.73	0.73	0.72	0.73	0.73	0.65	0.68	0.69	0.73

**Notes:** Each numbered column corresponds to a different robustness check. Robustness check (1) uses an interest rate without equity, (2) uses an interest rate with Standard and Poor's country-specific bond yields, (3) uses an interest rate including taxes, (4) assumes that profits cannot be negative, (5) drops the monetary policy instrument, (6) drops the uncertainty instrument, (7) uses no backcasting for instruments, and (8) backcasts non-manufacturing utilization data using industry-level regressions.

Table A.11: Robustness checks, United Kingdom

	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean TFP growth	1.06	1.07	1.05	1.06	1.09	1.06	1.06	1.06	1.06
Relative standard dev.	0.58	0.58	0.57	0.58	0.58	0.58	0.57	0.58	0.58
Corr. with real VA growth	0.20	0.20	0.21	0.20	0.21	0.20	0.24	0.19	0.20
<i>Corr. between TFP series</i>									
Baseline	.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Solow residual	0.52	0.52	0.52	0.52	0.53	0.52	0.57	0.51	0.52
BFK method	0.43	0.43	0.44	0.43	0.44	0.42	0.49	0.40	0.43

**Notes:** Each numbered column corresponds to a different robustness check. Robustness check (1) uses an interest rate without equity, (2) uses an interest rate with Standard and Poor's country-specific bond yields, (3) uses an interest rate including taxes, (4) assumes that profits cannot be negative, (5) drops the monetary policy instrument, (6) drops the uncertainty instrument, (7) uses no backcasting for instruments, and (8) backcasts non-manufacturing utilization data using industry-level regressions.

Table A.12: Robustness checks, United States

	Baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean TFP growth	0.83	0.84	0.78	0.85	0.87	0.83	0.83	0.83	0.83
Relative standard dev.	0.53	0.53	0.53	0.53	0.53	0.53	0.52	0.53	0.53
Corr. with real VA growth	0.34	0.33	0.31	0.33	0.34	0.34	0.35	0.32	0.34
<i>Corr. between TFP series</i>									
Baseline	.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Solow residual	0.70	0.70	0.68	0.70	0.73	0.70	0.70	0.66	0.70
BFK method	0.88	0.88	0.87	0.88	0.89	0.77	0.88	0.85	0.88

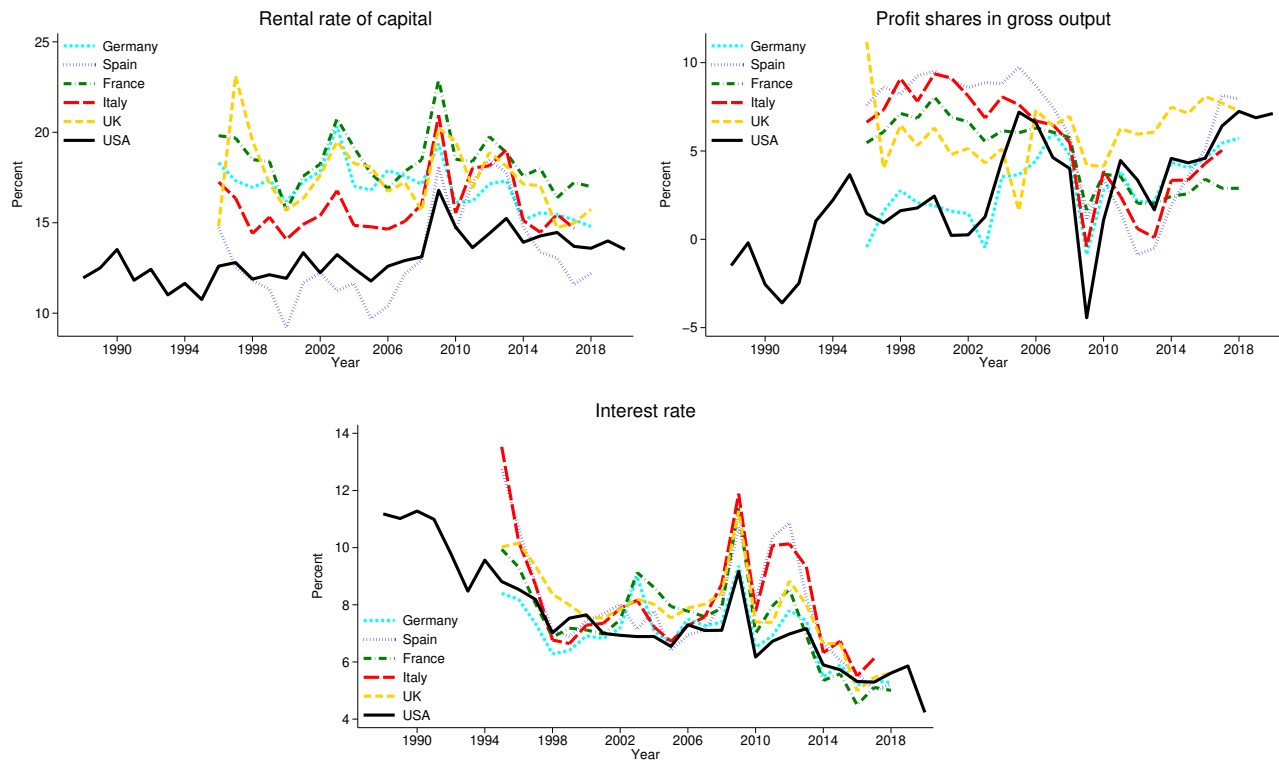
**Notes:** Each numbered column corresponds to a different robustness check. Robustness check (1) uses an interest rate without equity, (2) uses an interest rate with Standard and Poor's country-specific bond yields, (3) uses an interest rate including taxes, (4) assumes that profits cannot be negative, (5) drops the monetary policy instrument, (6) drops the uncertainty instrument, (7) uses no backcasting for instruments, and (8) backcasts non-manufacturing utilization data using industry-level regressions.

## D Additional results

### D.1 Rental rates and profit shares over time

To illustrate the behaviour of rental rates and profit shares over time, Figure A.9 plots the rental rate for the overall capital stock (top left panel), the profit share in gross output (top right panel) and our baseline interest rate (bottom panel). Rental rates are fairly stable over time, with a spike around the Great Recession in 2008-2009.<sup>64</sup> Rental rates are stable despite a decrease in interest rates, as they are more than compensated by an increase in depreciation rates. This increase, in turn, is due to a composition effect, as assets with higher depreciation rates (software, IT, R&D etc.) increase faster than others and have considerably higher depreciation rates.

Figure A.9: Rental rates, profit shares and interest rates



**Notes:** Rental rates are defined in equation (9), profit shares are defined in footnote 28. Both statistics are computed at the industry-level, and aggregated with value-added weights.

The right panel of Figure A.9 plots our estimates for profit shares. In the United States, our findings echo the ones of Barkai (2020): profits have risen substantially since the 1990s. The same is true for Germany. In the other four European countries, there is no clear

<sup>64</sup>Note that rental rates for the United States and Europe are not directly comparable, as EU KLEMS and the BLS use different definitions of capital: some expenditures are classified as material expenditures by the BLS and as investments by KLEMS, and vice-versa (see Appendix B.1).

trend.<sup>65</sup> Finally, to provide further detail, table A.13 lists a value-added-weighted average of industry BGP profit shares.<sup>66</sup>

Table A.13: Profit shares

	Germany	Spain	France	Italy	UK	USA
Percentage of gross output	2.9	6.2	4.7	5.5	6.0	2.3
Percentage of value added	6.1	15.5	11.9	12.9	13.6	4.9

**Notes:** BGP profit shares are time averages of profit shares. The table shows a value-added-weighted average of BGP profit shares across industries.

## D.2 TFP growth rates over time

Table A.14 lists average growth rates during the whole sample, as well as for the period before and after 2007.

Table A.14: Average TFP growth rates

	Germany	Spain	France	Italy	UK	EA	USA
<i>Overall sample</i>							
Solow residual	0.73	-0.33	0.28	-0.30	0.91	0.27	0.67
BFK method	0.76	-0.33	0.26	-0.33	0.92	0.28	0.68
Our method	0.58	-0.53	0.24	-0.27	1.06	0.20	0.83
<i>Subperiods, our method</i>							
1995-2007	0.77	-1.15	0.83	-0.29	1.60	0.29	1.49
2008-2018	0.37	0.14	-0.39	-0.24	0.48	0.08	0.38

**Notes:** EA stands for Euro Area, a value-added weighted average of TFP growth in Germany, Spain, France and Italy. TFP growth rates are expressed as log changes multiplied by 100.

The first panel shows that our method implies lower average TFP growth rates than the Solow or BFK methods for Germany and Spain, but higher growth rates in the UK and the US. The second panel confirms the productivity slowdown in the second half of the sample in Germany, France, the UK and the US. Spain is a notable exception to this pattern: here,

<sup>65</sup>Note that our focus on a BGP does not necessarily contradict the evolution of profit shares within countries. Indeed, even in the US, where estimated profits increased over the last 20 to 30 years, Karabarounis and Neiman (2019) have argued that profits are currently at the same level than in the 1960s. Thus, the data is consistent with low-frequency fluctuations around a stable long-run average.

<sup>66</sup>To deal with outliers, we winsorize BGP profit shares at  $-5\%$  to deal with outliers. Our results are unchanged with a threshold of  $-10\%$ , or if we do not allow for negative profits at all, as shown in Appendix C.4.

the Great Recession appears to end a long TFP decline. Tables A.15 to A.20 provide further details, by listing aggregate TFP growth rates for every single year and country.

Table A.15: TFP growth rates, Germany

	Solow residual	BFK method	Our method
1996	-0.33	0.43	0.95
1997	0.97	0.79	-0.41
1998	-0.20	-1.40	-0.78
1999	0.05	-0.18	0.47
2000	2.16	3.16	0.86
2001	1.21	1.34	2.31
2002	-0.05	0.07	1.02
2003	-0.58	-0.56	-1.22
2004	0.92	0.31	0.12
2005	1.92	3.14	1.78
2006	4.32	2.61	2.82
2007	2.33	1.65	1.32
2008	-1.60	-1.88	-0.95
2009	-7.86	-1.72	0.13
2010	4.52	-0.11	0.04
2011	2.83	0.95	-0.32
2012	0.38	2.67	1.22
2013	-0.16	0.36	0.36
2014	1.53	0.79	0.95
2015	0.35	0.12	0.20
2016	1.67	2.03	1.38
2017	2.38	2.77	1.51
2018	0.13	0.06	-0.39

**Notes:** TFP growth rates are expressed as log changes multiplied by 100.

Table A.16: TFP growth rates, Spain

	Solow residual	BFK method	Our method
1996	-2.80	-2.90	-3.32
1997	-1.21	-1.14	-2.79
1998	-1.00	-1.05	-2.07
1999	0.07	0.09	-0.26
2000	0.16	0.10	-1.11
2001	-0.16	0.01	-0.03
2002	-1.10	-1.17	-1.42
2003	-0.50	-0.64	-0.80
2004	-0.86	-0.72	-1.22
2005	0.44	0.45	-0.13
2006	0.93	0.92	-0.21
2007	-0.02	-0.07	-0.42
2008	-1.49	-1.51	-0.26
2009	-2.18	-1.96	1.90
2010	0.38	0.19	-0.02
2011	-0.56	-0.81	-0.65
2012	-1.08	-0.61	-0.17
2013	-1.42	-1.56	-1.28
2014	0.65	0.65	-0.12
2015	2.62	2.47	1.00
2016	0.32	0.40	0.07
2017	1.15	1.24	1.03
2018	0.08	0.03	0.03

**Notes:** TFP growth rates are expressed as log changes multiplied by 100.

Table A.17: TFP growth rates, France

	Solow residual	BFK method	Our method
1996	-0.17	-0.09	-0.04
1997	0.99	0.65	0.45
1998	2.35	2.07	2.18
1999	1.10	0.28	0.90
2000	2.85	3.74	2.26
2001	-0.99	-0.47	-1.18
2002	1.53	2.83	2.46
2003	0.72	-0.03	0.89
2004	0.20	-2.50	0.27
2005	0.43	0.94	0.04
2006	2.07	4.83	1.64
2007	0.55	-0.87	0.05
2008	-1.61	-1.99	-1.30
2009	-3.96	-1.93	-1.87
2010	0.91	-0.79	-0.04
2011	1.02	-0.07	0.06
2012	-1.23	-0.71	-0.82
2013	-0.13	1.00	0.75
2014	-0.37	0.01	-0.18
2015	0.05	-0.78	-0.09
2016	-0.24	-0.86	-0.53
2017	1.49	2.81	1.11
2018	-1.06	-2.04	-1.42

**Notes:** TFP growth rates are expressed as log changes multiplied by 100.

Table A.18: TFP growth rates, Italy

	Solow residual	BFK method	Our method
1996	-0.23	-0.77	0.51
1997	0.37	1.38	0.23
1998	-0.85	-2.18	-1.72
1999	-0.93	-1.11	-0.67
2000	2.29	3.42	1.42
2001	-0.40	-0.65	-0.14
2002	-2.09	-2.67	-1.18
2003	-1.71	-0.84	-1.86
2004	0.92	0.26	0.95
2005	-0.11	0.56	0.14
2006	0.05	-0.41	-0.85
2007	0.02	-1.38	-0.32
2008	-1.43	-0.92	-0.13
2009	-5.86	-2.14	-0.96
2010	2.81	-0.15	0.91
2011	0.20	-2.13	-1.18
2012	-1.81	0.79	-0.13
2013	0.03	0.63	-0.27
2014	0.18	-0.07	-0.59
2015	0.26	-0.32	-0.79
2016	0.77	0.47	0.47
2017	0.91	1.04	0.23

**Notes:** TFP growth rates are expressed as log changes multiplied by 100.

Table A.19: TFP growth rates, United Kingdom

	Solow residual	BFK method	Our method
1996	-0.15	-0.44	0.62
1997	-0.87	0.44	-1.82
1998	1.46	0.24	1.40
1999	0.50	0.65	2.43
2000	1.68	1.60	1.29
2001	1.60	1.63	2.68
2002	1.37	1.56	1.36
2003	2.41	2.67	3.07
2004	2.78	2.80	1.68
2005	2.71	2.22	3.78
2006	1.94	2.05	1.41
2007	2.14	1.83	1.24
2008	0.04	0.49	0.36
2009	-3.90	-3.72	0.54
2010	3.13	2.92	0.80
2011	0.68	0.58	-1.31
2012	-0.83	-0.68	-0.37
2013	0.71	0.42	1.19
2014	0.88	0.99	-0.32
2015	1.12	1.43	0.64
2016	-0.57	-1.05	0.41
2017	1.54	1.78	1.63
2018	0.54	0.83	1.65

**Notes:** TFP growth rates are expressed as log changes multiplied by 100.

Table A.20: TFP growth rates, United States

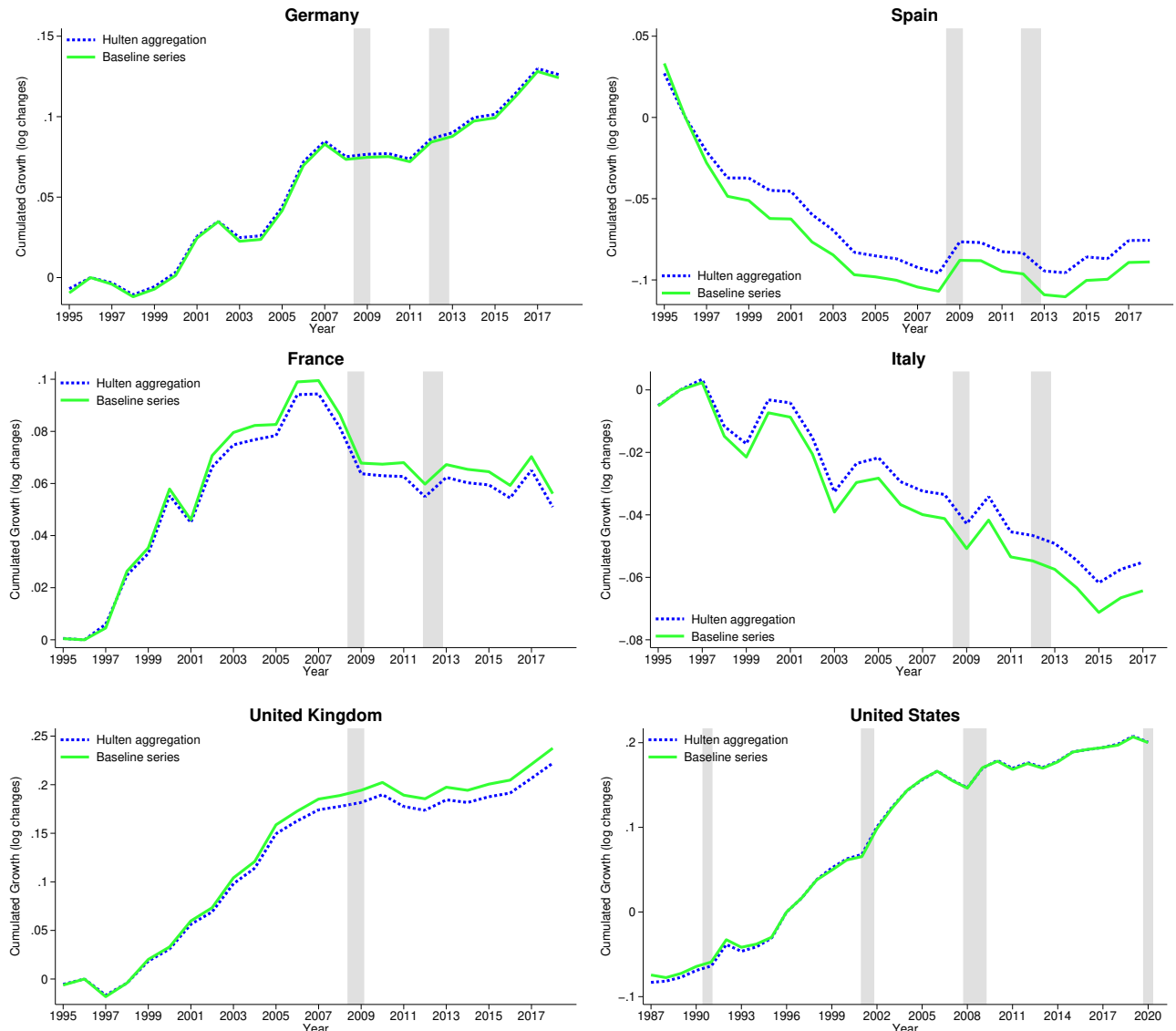
	Solow residual	BFK method	Our method
1988	1.28	0.42	-0.31
1989	0.25	-0.05	0.50
1990	0.37	1.39	0.81
1991	-0.47	-0.03	0.53
1992	2.92	2.72	2.63
1993	-0.77	-1.58	-0.89
1994	0.68	0.02	0.38
1995	0.19	1.44	0.80
1996	2.05	2.60	2.99
1997	1.56	0.81	1.65
1998	1.71	1.91	2.13
1999	1.18	0.53	1.16
2000	1.09	0.73	1.20
2001	-1.51	-0.12	0.40
2002	2.95	2.48	3.31
2003	2.29	2.44	2.41
2004	2.26	1.85	2.09
2005	1.52	1.77	1.32
2006	0.85	0.28	0.95
2007	-0.62	-0.58	-1.12
2008	-1.84	-1.49	-0.88
2009	-0.71	0.89	2.42
2010	3.48	1.69	0.76
2011	0.00	-0.14	-0.97
2012	0.86	1.04	0.69
2013	-1.15	-0.69	-0.55
2014	0.31	0.27	0.75
2015	0.63	0.81	1.16
2016	-0.11	0.00	0.32
2017	0.79	0.48	0.21
2018	1.22	0.63	0.28
2019	0.81	1.14	0.97
2020	-1.82	-1.24	-0.67

Notes: TFP growth rates are expressed as log changes multiplied by 100.

### D.3 Aggregation

This section investigates the importance of using cost-based Domar weights, as suggested in [Baqae and Farhi \(2019\)](#), for our overall results. Figure A.10 plots our baseline estimates of aggregate TFP growth against an alternative series that uses the baseline industry-level estimates of TFP growth, but aggregates them with standard sales-based Tornqvist-Domar weights rather than with our cost-based ones.

Figure A.10: The impact of different aggregation methods on estimated TFP growth



**Notes:** This figure plots our baseline measure of TFP growth against an alternative measure that uses sales-based Tornqvist-Domar weights for aggregation. Shaded areas mark recessions, defined in Appendix B.8.

Figure A.10 shows that for countries with high profit shares (such as Spain, France, Italy and the UK), consistent aggregation makes some difference. In these countries, the

cost-based Domar weights of [Baqae and Farhi \(2019\)](#) imply that TFP growth in upstream industries matters more for aggregate TFP growth. In France and the United Kingdom, where TFP growth in upstream industries is positive, this leads to an upward revision of overall TFP growth. In Spain and Italy, where TFP growth in upstream industries is negative, it leads to a downward revision. However, none of these changes affect cyclical patterns.

#### D.4 Regression results for disaggregate hours per worker proxies

As discussed in the main text, using aggregate hours per worker as a proxy for unobserved worker effort is problematic when there are composition effects.

Table A.21: BFK regression results with two types of hours per worker

	Germany	Spain	France	Italy	UK	USA
<i>Non-durable manufacturing</i>						
$\hat{\beta}_{H}^F$	0.554** (0.236)	-1.607* (0.859)	-0.034 (0.244)	0.487* (0.270)	-1.264 (1.332)	0.550 (0.522)
$\hat{\beta}_{H}^V$	0.067 (0.303)	-0.054 (0.175)	0.232** (0.102)	0.075 (0.187)	0.066 (0.121)	0.572 (0.924)
Observations	132	110	132	132	132	175
First-stage F-statistic	5.3	0.6	38.3	7.9	0.3	1.0
<i>Durable manufacturing</i>						
$\hat{\beta}_{H}^F$	0.852*** (0.247)	0.326 (0.601)	0.771*** (0.183)	0.701*** (0.185)	1.765*** (0.576)	1.673*** (0.629)
$\hat{\beta}_{H}^V$	-0.023 (0.302)	0.183** (0.077)	0.093 (0.104)	-0.094 (0.170)	-0.053 (0.123)	-0.000 (0.190)
Observations	132	110	132	132	132	275
First-stage F-statistic	4.8	1.5	37.9	7.7	2.1	3.8
<i>Non-manufacturing</i>						
$\hat{\beta}_{H}^F$	1.758** (0.736)	-1.239 (0.826)	0.522** (0.257)	0.656*** (0.242)	-1.786 (1.299)	-0.725 (0.452)
$\hat{\beta}_{H}^V$	-0.343** (0.159)	0.417 (0.866)	0.150 (0.304)	0.099 (0.145)	-0.632 (0.467)	0.769 (0.958)
Observations	286	286	286	286	286	775
First-stage F-statistic	7.8	0.5	4.4	9.4	0.9	2.1

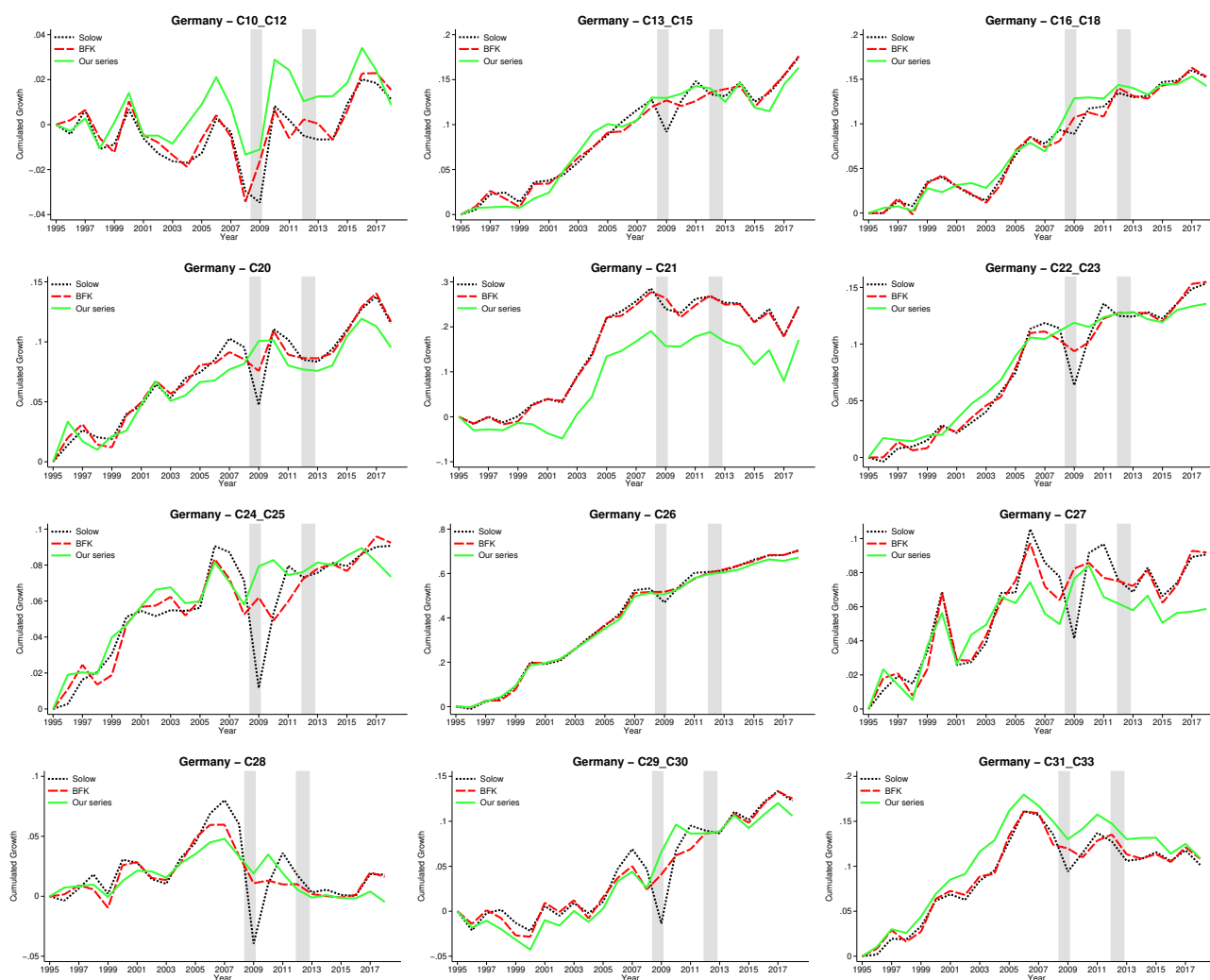
**Notes:** The coefficients  $\beta_{H}^F$  and  $\beta_{H}^V$  are estimated using 2SLS on equation (22), replacing changes in aggregate hours per worker by changes in hours per worker for the two subcategories of workers considered in this paper. Instruments are oil, monetary policy, uncertainty and financial shocks. The table reports Kleibergen-Paap rk Wald F statistics. Robust standard errors in parentheses. \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ .

In principle, this might be addressed by using disaggregate measures of hours per worker. Table A.21 shows the result of this approach, using both hours per worker of variable and quasi-fixed workers instead of aggregate hours per worker in the BFK regression specification (22). The results are not promising, with a first stage F-statistic that is generally very low, and many negative and/or insignificant second-stage coefficients. In practice, the instruments might not have enough power to predict two endogenous variables. Moreover, a positive correlation between the two proxies can also cause issues.<sup>67</sup>

## D.5 TFP growth at the industry level

In this section, we plot industry-level TFP growth rates for all European countries.

Figure A.11: Industry-level TFP growth, Germany



<sup>67</sup>Sanderson and Windmeijer (2016) show that the F-statistic with two endogenous variables - needs to be adjusted downward, implying that the first stage is even weaker than suggested by Table A.21.

Figure A.12: Industry-level TFP growth, Germany (continued)

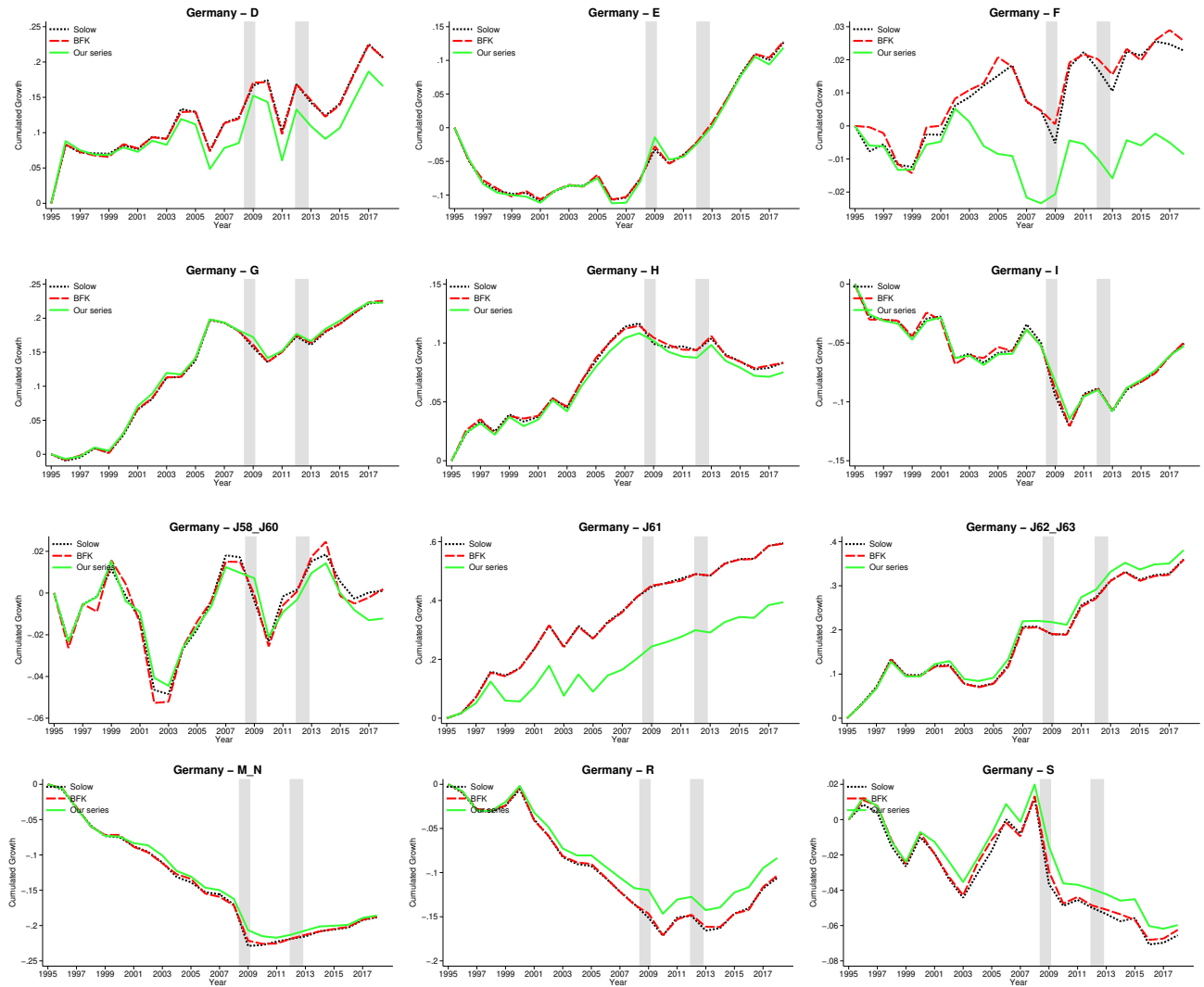


Figure A.13: Industry-level TFP growth, Spain

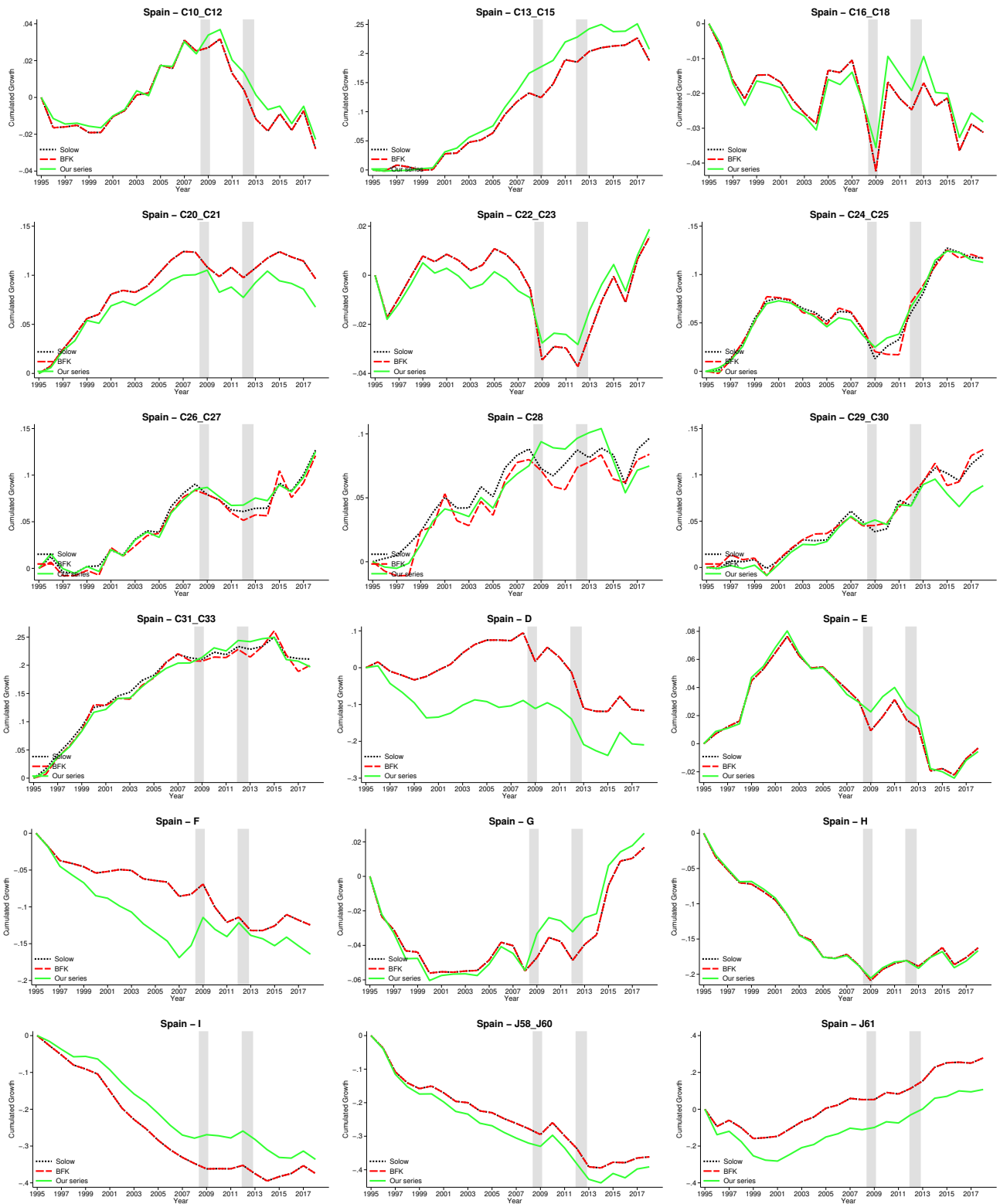


Figure A.14: Industry-level TFP growth, Spain (continued)

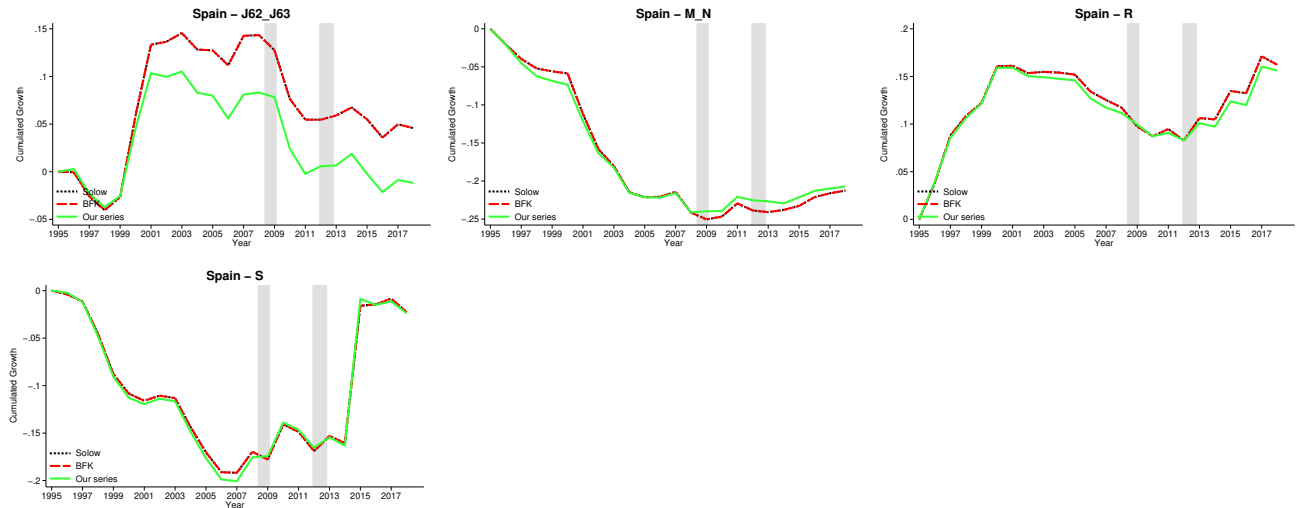


Figure A.15: Industry-level TFP growth, France

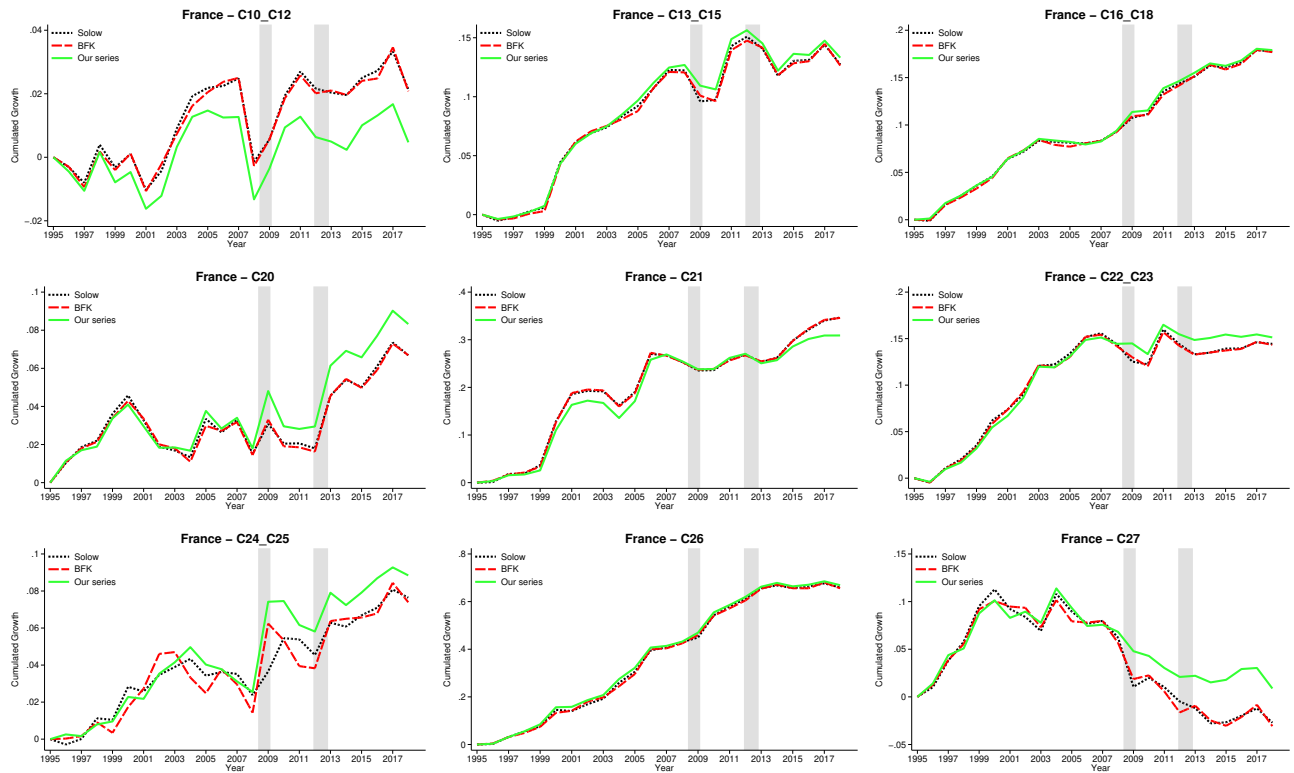


Figure A.16: Industry-level TFP growth, France (continued)

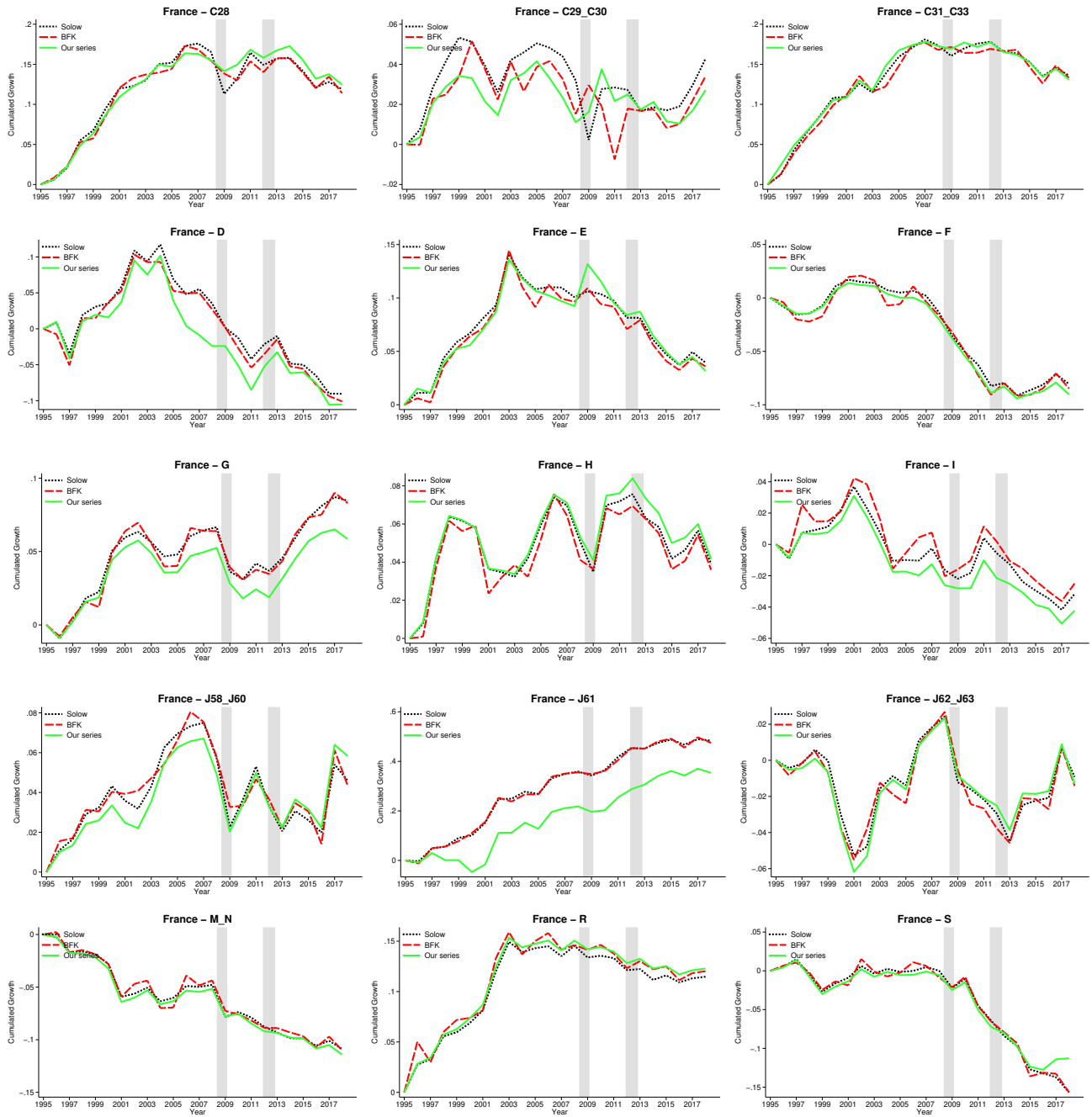


Figure A.17: Industry-level TFP growth, Italy



Figure A.18: Industry-level TFP growth, Italy (continued)

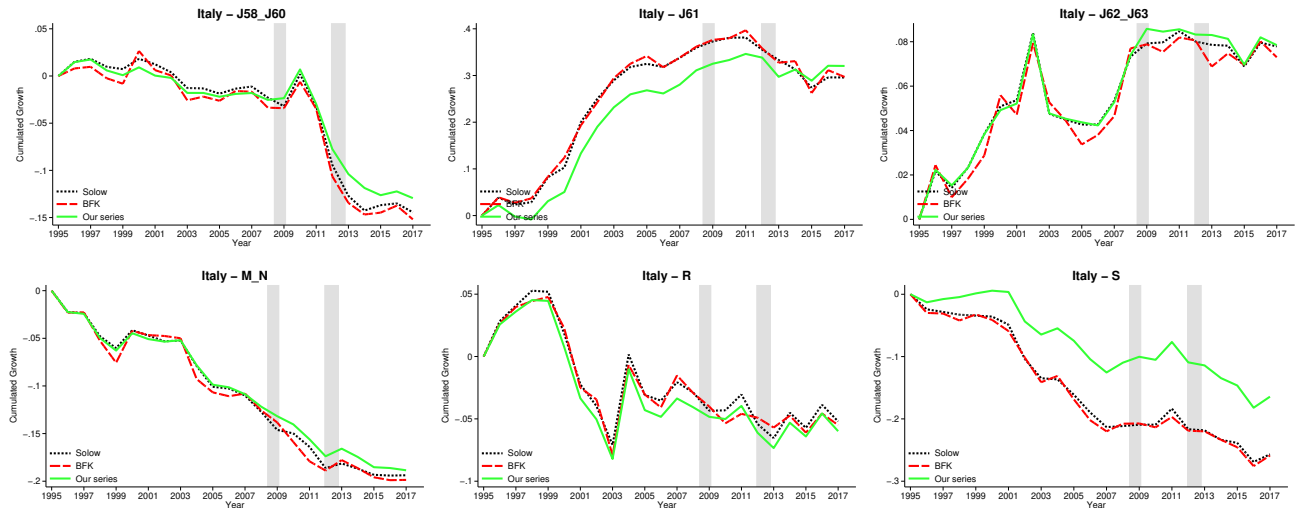


Figure A.19: Industry-level TFP growth, United Kingdom

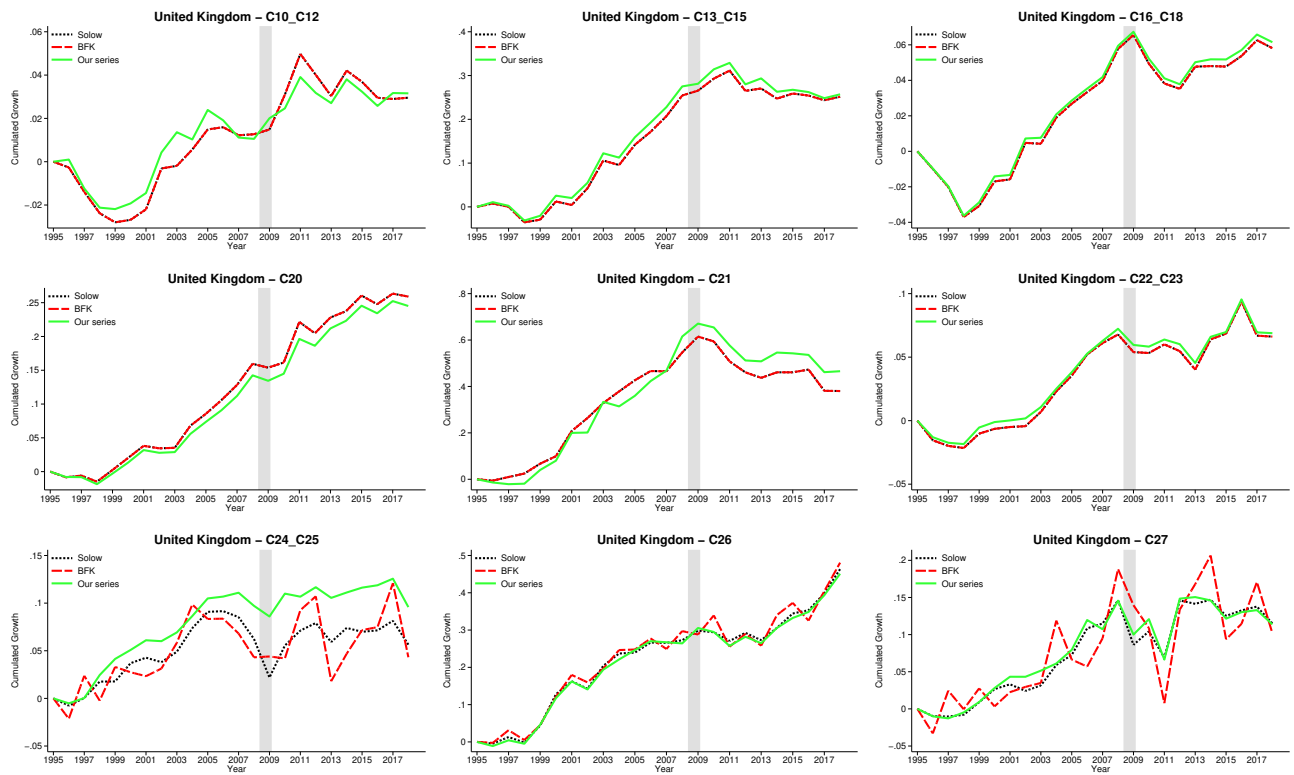
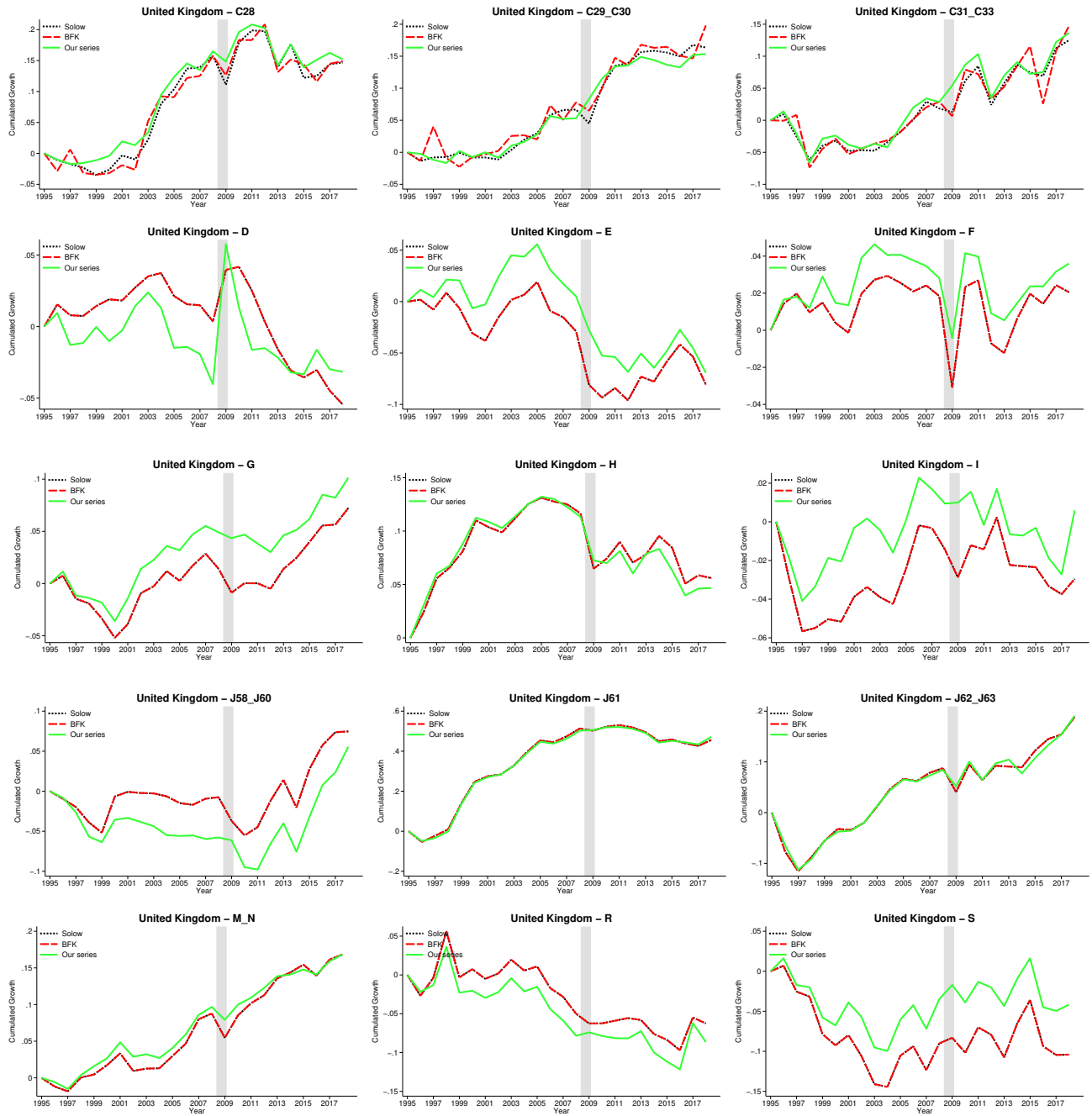


Figure A.20: Industry-level TFP growth, United Kingdom (continued)



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