To which extent does GDP volatility result from productivity volatility across sectors and firms?

M.-B. Khder    R. Monin

21-06-2018
Explaining the evolution over time of French GDP volatility

- Financial innovation enabling better allocation? Dynan et al. (2006)
- The share of highly volatile sectors in the economy has decreased: Carvalho and Gabaix (2013)
- High intra-firm volatility but low aggregate volatility, due to disintegrated innovations? Comin and Mulani (2006)

Figure: French GDP volatility

Volatility of the cyclical component (from Hodrick-Prescott filter) of log(real quarterly GDP)
Plan

1. Theoretical decomposition of aggregate volatility
   - Hulten
   - Carvalho Gabaix

2. Contribution of sectors to aggregate volatility

3. Contribution of firms to aggregate volatility
   - Firm-level fundamental volatility
   - An exploration of the determinants of firm-level volatilities
   - Wrap-up

4. Appendix
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Decomposing GDP growth into sectoral productivity shocks: Hulten (1978)’s model

To the first order, under the hypothesis of an efficient economy, GDP growth due to sectoral productivity growth is the sum of sectoral productivity growth \( \text{dlog}(A_i, t) \) weighted by Domar weights \( \lambda_{i,t} \) defined as the ratio of sector \( i \)'s nominal output to GDP

\[
d\log(Y) = \sum_{i=1}^{N} \lambda_i d\log(A_i)
\]

A strong result:

- The impact of sectoral productivities on GDP growth is described by a single sufficient statistics: Domar weights.
- In particular, it does not depend on Input-Output linkages, substitutability between sectors, returns to scale (Baqaee Farhi)
- Factor reallocation plays no role, because the economy is assumed to be efficient
- If the law of large numbers applies to the Domar weights distribution, then no granularity effect (Lucas(1977), Dupor (1999))
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Tracking GDP volatility: Carvalho and Gabaix (2013)’s model

- Variance of $dlog(Y_t) = \sum_{i=1}^{N} \lambda_{i,t} dlog(A_{i,t})$ Hulten’s 1st-order GDP approx.

$$Var[dlog(Y_t)] \approx \sum_{i=1}^{N} Var[\lambda_{i,t} dlog(A_{i,t})] + \sum_{i=1}^{N} \sum_{j=1}^{N} Cov[\lambda_{i,t} dlog(A_{i,t}), \lambda_{j,t} dlog(A_{j,t})]$$

- Under the additional assumptions of (i) independence across distinct sectors, (ii) "relatively stable" Domar weights and (iii) constant-over-time sectoral productivity variance, GDP volatility can be tracked to the first-order by Carvalho and Gabaix’s fundamental volatility indicator $\sigma_{F,t}$

$$\sigma_{F,t} = \sqrt{\sum_{i=1}^{n} \left(\lambda_{i,t}\right)^2 (\sigma_{i,tfp})^2}$$

where $(\sigma_{i,tfp})^2 \equiv Var[dlog(A_{i,t})]$ variance of $i$’s total factor productivity growth, and $\lambda_{i,t}$ $i$’s Domar weight defined as the ratio of $i$’s nominal sales to GDP
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Theory

Contribution of sectors to aggregate volatility
Contribution of firms to aggregate volatility
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Building the sectoral fundamental volatility

Goal: Estimating the model

\[ \sigma_{\text{PIB cyc}}^{\text{Rol}, 10} = a + b \sqrt{\sum_i (\lambda_{i,t})^2 (\sigma_{i, \text{tfp}}^t)^2 + \epsilon_t} \]

- GDP volatility \( \sigma_{\text{PIB cyc}}^{\text{Rol}, 10} \): 10-year rolling standard deviation of the first-difference of the cyclical component (from Hodrick-Prescott filtering) of the French quarterly log(real GDP)
- Sectoral data from the National Accounts, Insee: 1978-2014, A38 disaggregation
- Sectoral total factor productivities à la Timmer et O’Mahoni (2009)

\[ tfp_{i,t} \equiv \ln Q_{i,t} - \left[ \bar{s}_{i,t}^M \ln M_{i,t} + \bar{s}_{i,t}^L \ln L_{i,t} + \bar{s}_{i,t}^K \ln K_{i,t} \right] \]

\[ s_{i,t}^M = \frac{p_{i,t}^M M_{i,t}}{p_{i,t}^Q Q_{i,t}}; \quad s_{i,t}^L = \frac{Sal_{i,t}}{p_{i,t}^Q Q_{i,t}}; \quad s_{i,t}^K = \frac{OS_{i,t}}{p_{i,t}^Q Q_{i,t}}; \quad \lambda_{i,i} = \frac{p_{i,t}^Q Q_{i,t}}{GDP_t^{\text{nom}}}; \quad (\sigma_{i, \text{tfp}}^t)^2 = \text{Var}[\Delta tfp_{i,i}] \]

where \( Q_{i,t} \) sector \( i \)'s real production in year \( t \), \( M_{i,t} \) real intermediate input consumption, \( L_{i,t} \) hours worked, \( K_{i,t} \) real capital stock, \( p_{X}^t \) price of \( X \in [Q, M, ...] \), \( Sal_t \) payroll, \( OS_t \) operating surplus, \( \bar{s}_{i,t}^X \) 3-year moving average of \( s_{i,t}^X \).

M.-B. Khder, R. Monin

To which extent does GDP volatility result from productivity?
The fundamental volatility explains 27-35% of GDP volatility after 1986, but its explanatory power is very low before 1986!

<table>
<thead>
<tr>
<th>Model</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Regressors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sqrt{\sum_i (\lambda_{i,t})^2 (\sigma_{i,tfp})^2}$</td>
<td>-0.300***</td>
<td>2.157***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.362)</td>
<td>(0.717)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sqrt{\sum_i (\lambda_{i,t})^2 (\sigma_{i,tfp,Rol.8})^2}$</td>
<td></td>
<td></td>
<td>0.0573</td>
<td>0.841***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.164)</td>
<td>(0.232)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.0186***</td>
<td>-0.0235*</td>
<td>0.0126***</td>
<td>0.00225</td>
</tr>
<tr>
<td>(0.00648)</td>
<td>(0.0124)</td>
<td>(0.00241)</td>
<td>(0.00318)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>32</td>
<td>26</td>
<td>29</td>
<td>26</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.022</td>
<td>0.274</td>
<td>0.004</td>
<td>0.353</td>
</tr>
<tr>
<td>Standard errors in parentheses; *** p&lt;0.01, ** p&lt;0.05, * p&lt;0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Plan

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   - Hulten
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Firm-level fundamental volatility and aggregate volatility

- Fundamental volatility indicator $\sigma_{Ft}^{\text{ent}}$ based on firm-level productivities:
  \[
  \sigma_{Ft}^{\text{ent}} = \sqrt{\sum_i \left( \frac{S_{it}}{Y_t} \right)^2 \sigma^2_{\omega,i,t}}
  \]
  - $Y_t$ is the sum of value added of firms in the sample in year $t$, $S_{it}$ the nominal sales of firm $i$ in year $t$, $\sigma^2_{\omega,i,t}$ the 5-y rolling window variance of firm-level TFP growth.
  - TFP estimation

- Our sample excludes firms in the sectors of agriculture, banking and insurance, mining and quarrying, refined petroleum industries, electricity, gas, air-conditioning, water supply and waste management, public administration, teaching, social work activities and health.

Figure: Firm-level fundamental and aggregate volatility

Firm-level fundamental volatility is based on French tax declarations: databases SUSE and ESANE. Aggregate volatility is based on national accounts data.
The change over time in firm-level productivity volatilities should be taken into account

\[ \sigma_{Ft}^{\text{ent}} = \sqrt{\sum_i \left( \frac{S_{it}}{Y_t} \right)^2 \sigma_{\omega, i, t}^2} \]

- \( S_{it} \) the nominal sales of firm \( i \) in year \( t \),
- \( \sigma_{\omega, i, t}^2 \) the 5-y rolling window variance of firm-level TFP growth.

\[ \sigma_{Ft}^{\text{ent}} = \sqrt{\sum_i \left( \frac{Y_{it}}{Y_t} \right)^2 \sigma_{\omega, i}^2} \]

- \( Y_{it} \) nominal value-added of firm \( i \),
- \( \sigma_{\omega, i}^2 \) -constant- variance of firm-level TFP growth (computed over 1989-2015).

To which extent does GDP volatility result from productivity volatility across sectors and firms?
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Defining consistently firm-level volatility

To study the variability of volatility over time and to take into account firm entry/exit sample and mild data collection issues, we define firm-level volatility

\[ s_{it} = \sqrt{v_{it}} \]

as in Thesmar and Thoenig (2011):

\[ v_{it} = \left( \frac{N_{it}}{N_{it} - 1} \right) \left( \frac{1}{N_{it}} \sum_{s=t-2}^{t+2} g_{is}^2 - \left( \frac{1}{N_{it}} \sum_{s=t-2}^{t+2} g_{is} \right)^2 \right) \]

Where \( N_{it} \) is the number of observation years for firm \( i \) between \( t - 2 \) and \( t + 2 \) and \( g_{it} \) a measure of production, value added, total factor productivity or employment growth.

NB: Is represented \( \sqrt{\sum_i \theta_{i,t} v_{i,t}} \) where \( v_{i,t} \) is respectively the corrected variance of firm \( i \)'s production growth, factors growth and tfp growth; \( \theta_{i,t} \) is the production share in the sample.
From 1990 till 2010, overall downward trend in the variance of the firm-level production growth, of the firm-level input usage growth and of the firm-level TFP growth

The variance of the firm-level production growth rates depends mainly on the variance of the firm-level input usage growth.

No significant increase in firm-level production, input and TFP volatilities during the Great Recession, contrasting with aggregate volatility.

The variance of the firm-level total factor productivity growth exhibits a puzzling upward trend after 2012.

The positive covariance between firm-level input usage growth and TFP growth over the period 1990-2012 fails since 2012.
Table 9 – Average firm-level volatility: 1990-2004 and 2005-2015

<table>
<thead>
<tr>
<th>Sector</th>
<th>Average volatility</th>
<th>Volatility drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>food products, beverages and tobacco products</td>
<td>0.158</td>
<td>0.143</td>
</tr>
<tr>
<td>textiles, wearing apparel</td>
<td>0.189</td>
<td>0.158</td>
</tr>
<tr>
<td>wood and paper products</td>
<td>0.163</td>
<td>0.150</td>
</tr>
<tr>
<td>chemicals and chemical</td>
<td>0.161</td>
<td>0.181</td>
</tr>
<tr>
<td>pharmaceutical products</td>
<td>0.175</td>
<td>0.157</td>
</tr>
<tr>
<td>rubber, plastics, non-metallic mineral products</td>
<td>0.143</td>
<td>0.145</td>
</tr>
<tr>
<td>metal products, except machinery and equipment</td>
<td>0.177</td>
<td>0.185</td>
</tr>
<tr>
<td>computer, electronic and optical products</td>
<td>0.219</td>
<td>0.176</td>
</tr>
<tr>
<td>electrical equipment</td>
<td>0.209</td>
<td>0.150</td>
</tr>
<tr>
<td>machinery and equipment n.e.c.</td>
<td>0.220</td>
<td>0.219</td>
</tr>
<tr>
<td>transport equipment</td>
<td>0.185</td>
<td>0.150</td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>0.210</td>
<td>0.173</td>
</tr>
<tr>
<td>Construction</td>
<td>0.257</td>
<td>0.228</td>
</tr>
<tr>
<td>Wholesale and retail trade; repair of motor vehicles</td>
<td>0.178</td>
<td>0.156</td>
</tr>
<tr>
<td>Transportation and storage</td>
<td>0.149</td>
<td>0.135</td>
</tr>
<tr>
<td>Accommodation and food service activities</td>
<td>0.156</td>
<td>0.131</td>
</tr>
<tr>
<td>Publishing, audiovisual and broadcasting activities</td>
<td>0.180</td>
<td>0.179</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>0.100</td>
<td>0.111</td>
</tr>
<tr>
<td>IT and other information services</td>
<td>0.203</td>
<td>0.183</td>
</tr>
<tr>
<td>Real estate activities</td>
<td>0.224</td>
<td>0.186</td>
</tr>
<tr>
<td>Legal, accounting, STEMS jobs</td>
<td>0.221</td>
<td>0.234</td>
</tr>
<tr>
<td>Scientific research and development</td>
<td>0.178</td>
<td>0.198</td>
</tr>
<tr>
<td>Other professional, scientific and technical activities</td>
<td>0.261</td>
<td>0.194</td>
</tr>
<tr>
<td>Administrative and support service activities</td>
<td>0.202</td>
<td>0.179</td>
</tr>
</tbody>
</table>
A pervasive decrease in firm-level production volatility... but an increase in TFP and labor volatility

- The drop in firm-level production volatility is pervasive across sectors...
- and affects the whole distribution

"Prod vol" represents the square root of the weighted (by the production share) average of firm-level production growth variances in the sample. "L. Vol." is defined similarly except it considers labor growth volatility, "K. Vol." capital growth volatility, "M. Vol." materials growth volatility, and "TFP Vol." the volatility of total factor productivity growth.

Figure: Firm-level volatility of production, inputs and productivity
Determinants of firm-level production volatility

Regression model:

$$\sqrt{v_{it}} = \alpha + \beta X_{it} + \delta_j + \delta_t + \epsilon_{it}$$

With $\sqrt{v_{it}}$ alternatively referring to the volatility of firm-level value added or production, $\delta_j$ sectoral fixed effects (firm $i \in$ sector $j$) and $\delta_t$ year dummies. Controls $X_{it}$ include:

- the workforce turnover defined as the sum of employees that were hired and that quited firm the firm during the year, divided by average workforce
- the investment rate (investment in tangible asset divided by value added)
- dummy for exporter status
- the export ratio (export sales divided by total sales)
- TFP growth
- a dummy if the firm belongs to a corporate group
- a geographic scope variable variable (values 1 if the firm is present in only one département, two, or more than two
- a categorical variable for firm size in workforce (0 to 10, 10 to 20, 20 to 50, 50 to 250 and more than 250)
- a dummy variable indicating if year $t$ is the last year of presence of firm $i$
### Firm-level fundamental volatility

**An exploration of the determinants of firm-level volatilities**

**Wrap-up**

<table>
<thead>
<tr>
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<th>Appendix</th>
</tr>
</thead>
</table>

To which extent does GDP volatility result from productivity volatility across sectors and firms?

<table>
<thead>
<tr>
<th></th>
<th>Volatility : total production</th>
<th>Volatility : value added</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \hat{\beta} )</td>
<td>( \hat{\sigma} )</td>
</tr>
<tr>
<td>Workforce turnover lagged</td>
<td>0.0418***</td>
<td>(0.000372)</td>
</tr>
<tr>
<td></td>
<td>0.0431***</td>
<td>(0.000371)</td>
</tr>
<tr>
<td>Investment rate lagged</td>
<td>-0.000763***</td>
<td>(0.0000485)</td>
</tr>
<tr>
<td></td>
<td>0.0000494</td>
<td>(0.0000422)</td>
</tr>
<tr>
<td>Export status lagged</td>
<td>0.0105***</td>
<td>(0.000218)</td>
</tr>
<tr>
<td></td>
<td>0.00830***</td>
<td>(0.000218)</td>
</tr>
<tr>
<td>Export rate lagged</td>
<td>0.0420***</td>
<td>(0.000728)</td>
</tr>
<tr>
<td></td>
<td>0.0349***</td>
<td>(0.000728)</td>
</tr>
<tr>
<td>TFP growth</td>
<td>0.0184***</td>
<td>(0.000460)</td>
</tr>
<tr>
<td>Belongs to a group</td>
<td>0.00832***</td>
<td>(0.000132)</td>
</tr>
<tr>
<td>Geographical scope</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 départements</td>
<td>0.00866***</td>
<td>(0.000297)</td>
</tr>
<tr>
<td>&gt;2 départements</td>
<td>0.00476***</td>
<td>(0.000438)</td>
</tr>
<tr>
<td>Average workforce</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[10-20]</td>
<td>-0.0230***</td>
<td>(0.000157)</td>
</tr>
<tr>
<td>[20-50]</td>
<td>-0.0341***</td>
<td>(0.000193)</td>
</tr>
<tr>
<td>[50-250]</td>
<td>-0.0465***</td>
<td>(0.000287)</td>
</tr>
<tr>
<td>[&gt;250]</td>
<td>-0.0724***</td>
<td>(0.000579)</td>
</tr>
<tr>
<td>Last year in sample</td>
<td>0.0237***</td>
<td>(0.000218)</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>5395850</td>
<td>5395850</td>
</tr>
<tr>
<td><strong>adj. R-sq</strong></td>
<td>0.95</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Source: SUSE - ESANE - DADS - LIFI.
Scope: scope of study, 1994-2015 Estimation with sector and year fixed-effects.
Standard errors in parenthesis écart-types entre parenthèses. ; **p<0.05 ; *** p<0.01 ; **** p<0.001
The decrease in firm-level volatility cannot be explained by change in composition

The drop in firm-level volatilities cannot be explained by a change in observables

Figure: Regression year fixed effects

M.-B. Khder, R. Monin

To which extent does GDP volatility result from productivity across sectors and firms?
Does granularity explain aggregate volatility?

Figure: Volatility of large firms, of all firms and aggregate production volatility

M.-B. Khder, R. Monin

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Accounting for aggregate volatility with firm-level indicators: taking stock

From an accounting standpoint, the variance of the growth of aggregate production depends +/- on

- (+) The variance of the share of exiters minus the share of entrants at each period
- (-) The covariance between production growth for the continuers and the difference (share of exiters - share of entrants)
- (+) The variance of production growth of for continuers ("intensive margin") :

The variance of production growth for continuers itself depends positively on:

- (+) The \( \star \star \star \) variance of the firm-level production growth rate times the share of production by the firm among the production of all the continuers at the previous date
- (+) The covariance among different firms of the firm-level production growth rate times the share of the production by the firm among continuers

Under the -strong- assumption that the production share of the continuing firms are less volatile than their production growth rate, the study of \( \star \star \star \) boils down to that of the variance of the firm-level production growth rates (weighted by squared production shares).
The variance of the firm-level production growth rates can be further broken down and depends positively on:

- (+) The variance of the firm-level input usage growth among the continuers
- (+) The variance of the firm-level total factor productivity growth among the continuers
- (+) The covariance between firm-level input usage growth and firm-level total factor productivity growth
Conclusion

- Tracking aggregate volatility with sector-level and firm-level fundamental volatilities remains perilous.
- Productivity volatilities change significantly over time, both at the sectoral and the firm-level.
- We document a pervasive drop in production volatility since 2007 [strictly speaking]/ the beginning of the 2000s [loosely speaking] till now.
- The pervasive drop in firm-level production volatility mirrors a simultaneous drop in input usage volatility and productivity volatility till 2011.
- Firm-level employment and productivity volatilities exhibit a puzzling upward pattern since 2011.


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If the economy is subjected to several simultaneous sectoral technological shocks \((\text{dlog}(A_i))_{i=1}^N\) with mean zero and of variance-covariance matrix \(\Sigma = (s_{i,j})_{1 \leq i,j \leq N}\), then idiosyncratic sectoral productivity shocks interact, so that:

\[
d\text{log}(Y) = \sum_i \lambda_i d\text{log}A_i
+ \frac{1}{2} \sum_i \sum_{j \neq i} \left[ \frac{\lambda_i}{\xi} \sum_{k \neq j} \lambda_k (1 - \frac{1}{\rho_{j,k}}) + \lambda_i \frac{d\text{log}\xi}{d\text{log}A_j} - \lambda_i (1 - \frac{1}{\rho_{j,i}}) \right] d\text{log}A_i d\text{log}A_j
+ N \sum_{i=1}^N \lambda_i (d\text{log}A_i)^2
\]

where:

- \(\lambda_i\) refers to the Domar weight of sector \(i\),
- \(\xi\), which is defined as the sum of Domar weights across all sectors, can be interpreted as an input-output multiplier,
- \(\rho_{i,j}\) corresponds to a macro-elasticity of substitution between sectors \(i\) and \(j\), \(\rho_{i,j} \in [0, 1]\) meaning \(i\) and \(j\) are complementary, and substitutable otherwise.
Baqee and Farhi (2017)'s improvement on Hulten's model

Model ($M_k$)

$$\Delta y_t^{cyc} = \alpha + \beta \sum_i \left( \frac{p_{i,t}^Q Q_{i,t}}{p_t^Y Y_t} \right) \Delta tfp_i + \gamma (\Delta tfp_k)^2 + \epsilon_t$$

- where $k$ is a sector selected because of its strategic contribution
- $\Delta y_t^{cyc}$ represents the first difference of the cycle of $y_t$ log real GDP,
- $\frac{p_{i,t}^Q Q_{i,t}}{p_t^Y Y_t}$ is Domar’s weight of the sector $i$
- $\Delta tfp_i$ the growth of sector $i$’s productivity.
Table 3 – Influence of second-order sectoral productivity shocks on GDP growth

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>benchmark</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sum_i \left( \frac{p_{i,t}^2}{p_{i,t}} \right) \Delta t_f p_i$</td>
<td>0.00937</td>
<td>0.132*</td>
<td>0.140**</td>
<td>0.126*</td>
<td>0.143*</td>
<td>0.425***</td>
</tr>
<tr>
<td></td>
<td>(0.0385)</td>
<td>(0.0655)</td>
<td>(0.0681)</td>
<td>(0.0682)</td>
<td>(0.0729)</td>
<td>(0.0658)</td>
</tr>
<tr>
<td>$(\Delta t_f p_{K2,t})^2$</td>
<td>-0.0183</td>
<td>0.00388</td>
<td>0.0245</td>
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<tr>
<td></td>
<td>(0.0363)</td>
<td>(0.0396)</td>
<td>(0.0497)</td>
<td></td>
<td></td>
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<tr>
<td>$(\Delta t_f p_{Z,t})^2$</td>
<td>-0.708</td>
<td></td>
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<tr>
<td></td>
<td>(1.012)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>$(\Delta t_f p_{C,t})^2$</td>
<td>-0.917**</td>
<td>-0.933**</td>
<td>-0.722</td>
<td>-0.743</td>
<td>-0.629</td>
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</tr>
<tr>
<td></td>
<td>(0.408)</td>
<td>(0.414)</td>
<td>(0.439)</td>
<td>(0.444)</td>
<td>(0.403)</td>
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<tr>
<td>$(\Delta t_f p_{H,t})^2$</td>
<td>-0.883</td>
<td>-0.878</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(0.671)</td>
<td>(0.677)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Constant</td>
<td>-0.00222</td>
<td>-0.00354</td>
<td>-0.00320</td>
<td>-0.00193</td>
<td>-0.00191</td>
<td>0.0133***</td>
</tr>
<tr>
<td></td>
<td>(0.00317)</td>
<td>(0.00305)</td>
<td>(0.00316)</td>
<td>(0.00327)</td>
<td>(0.00330)</td>
<td>(0.00251)</td>
</tr>
</tbody>
</table>

Observations: 36  36  36  36  36  29
R-squared: 0.002  0.134  0.141  0.187  0.200  0.652

Dependent Variable: $\Delta y_{it}^{20}$

Estimation period: 1979-2014

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

C2: Manufacture of coke and refined petroleum products
FZ: Construction
GZ: Wholesale and retail trade; repair of motor vehicles and motorcycles
HZ: Transportation and storage
KZ: Financial and insurance activities
LZ: Real estate activities

To which extent does GDP volatility result from productivity volatility across sectors and firms?
Computing firm-level TFP 1/3

\[ y_{it} = \alpha_0 + \beta_K k_{it} + \beta_L l_{it} + \beta_M m_{it} + \omega_{it} + \epsilon_{it} \]

where \( y_{it} \) the log total production (sum of turnover, capitalised and stored production) of firm \( i \) in year \( t \); \( l_{it} \) the log of average workforce (from tax declarations), \( k_{it} \) the log of capital volume, and \( m_{it} \) the log of intermediate consumption (raw materials, commodities, merchandises, and external costs, that include for instance energy bills). \( \omega_{it} \) is the TFP, \( \epsilon_{it} \) the error term.

Levinsohn and Petrin (2003) estimation: correction of the bias created by the simultaneity between productivity (\( \omega_{it} \)) realisation and the choice of inputs \( l_{it} \) and \( m_{it} \), under the double hypothesis that (i) \( \{ \omega_{i0}, \omega_{i1}...\omega_{it} \} \) is a Markov process and that (ii) the demand for intermediate consumption is a function of \( k_{it} \) and \( \omega_{it} \), strictly increasing with the productivity \( \omega_{it} \).

Two step-estimation: (1) use a control function (second order polynomial) of \( k \) and \( m \) to identify \( \beta_L \) and \( \beta_M \), under the hypothesis that the capital stock \( k \) cannot immediately adjust to contemporaneous productivity shock \( \omega_{it} \), and that the contemporaneous productivity shock \( \omega_{it} \) is independent from intermediate consumption at time \( t - 1 \) (2) a proxy of \( \omega_{it} \) is used to recover the capital coefficient \( \beta_K \).
Computing firm-level TFP 2/3

\[ y_{it} = \alpha_0 + \beta_K k_{it} + \beta_L l_{it} + \beta_M m_{it} + \omega_{it} + \epsilon_{it} \]

- The values for turnover, value-added and intermediate consumption are deflated respectively by the corresponding sectoral price indexes computed by the french national accounts (level of dis-aggregation : A38).

- Values for capital stock in volume are computed based on tangible assets values reported in tax declarations (land, buildings, technical equipment and industrial material; other tangible asset including in particular informatic and transportation assets). Since tangible assets are accounted at their face value when they are bought, we estimate a volume of capital by applying a the corresponding price index at the estimated date of acquisition. This date is estimated with the average capital vintage, obtained with the amortised part of capital multiplied by the usual lifetime of the different tangible assets, cf inter alia by Cette et al. (2017) recently.

- Standards errors for estimates are computed with bootstrap.
### Table 8 - Coefficients from Levinsohn Petrin estimation

<table>
<thead>
<tr>
<th>Secteur</th>
<th>Capital</th>
<th>Labor</th>
<th>Int. Cons.</th>
<th>N. obs</th>
<th>N. firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>food products, beverages and tobacco products</td>
<td>4%</td>
<td>22%</td>
<td>75%</td>
<td>216 963</td>
<td>23 188</td>
</tr>
<tr>
<td>textiles, wearing apparel</td>
<td>4%</td>
<td>37%</td>
<td>69%</td>
<td>110 959</td>
<td>13 281</td>
</tr>
<tr>
<td>chemicals and chemical products</td>
<td>5%</td>
<td>13%</td>
<td>83%</td>
<td>39 042</td>
<td>3 465</td>
</tr>
<tr>
<td>pharmaceutical products</td>
<td>7%</td>
<td>12%</td>
<td>81%</td>
<td>7 257</td>
<td>674</td>
</tr>
<tr>
<td>rubber, plastics, non-metallic mineral products</td>
<td>6%</td>
<td>21%</td>
<td>73%</td>
<td>124 715</td>
<td>10 873</td>
</tr>
<tr>
<td>metal products, except machinery and equipment</td>
<td>5%</td>
<td>30%</td>
<td>67%</td>
<td>276 529</td>
<td>22 540</td>
</tr>
<tr>
<td>computer, electronic and optical products &amp; opt.</td>
<td>10%</td>
<td>17%</td>
<td>71%</td>
<td>39 315</td>
<td>4 326</td>
</tr>
<tr>
<td>electrical equipment</td>
<td>4%</td>
<td>23%</td>
<td>73%</td>
<td>31 364</td>
<td>2 956</td>
</tr>
<tr>
<td>machinery and equipment n.e.c.</td>
<td>4%</td>
<td>24%</td>
<td>73%</td>
<td>79 216</td>
<td>7 701</td>
</tr>
<tr>
<td>transport equipment</td>
<td>2%</td>
<td>24%</td>
<td>76%</td>
<td>36 407</td>
<td>3 237</td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>4%</td>
<td>32%</td>
<td>70%</td>
<td>270 325</td>
<td>30 247</td>
</tr>
<tr>
<td>Construction</td>
<td>3%</td>
<td>28%</td>
<td>63%</td>
<td>1 182 235</td>
<td>141 660</td>
</tr>
<tr>
<td>Wholesale and retail trade; repair of motor vehicles</td>
<td>2%</td>
<td>17%</td>
<td>85%</td>
<td>3 083 677</td>
<td>358 879</td>
</tr>
<tr>
<td>Transportation and storage</td>
<td>6%</td>
<td>27%</td>
<td>71%</td>
<td>399 293</td>
<td>44 115</td>
</tr>
<tr>
<td>Accommodation and food service activities</td>
<td>4%</td>
<td>21%</td>
<td>79%</td>
<td>498 866</td>
<td>70 082</td>
</tr>
<tr>
<td>Publishing, audiovisual and broadcasting activities</td>
<td>9%</td>
<td>32%</td>
<td>73%</td>
<td>145 036</td>
<td>20 657</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>2%</td>
<td>14%</td>
<td>84%</td>
<td>7 784</td>
<td>1 401</td>
</tr>
<tr>
<td>IT and other information services</td>
<td>5%</td>
<td>43%</td>
<td>64%</td>
<td>137 881</td>
<td>22 046</td>
</tr>
<tr>
<td>Real estate activities</td>
<td>18%</td>
<td>33%</td>
<td>45%</td>
<td>538 251</td>
<td>79 598</td>
</tr>
<tr>
<td>Legal, accounting, STEMS jobs</td>
<td>5%</td>
<td>46%</td>
<td>60%</td>
<td>703 992</td>
<td>98 514</td>
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<tr>
<td>Scientific research and development</td>
<td>5%</td>
<td>31%</td>
<td>68%</td>
<td>11 127</td>
<td>1 539</td>
</tr>
<tr>
<td>Other professional, scientific and technical activities</td>
<td>4%</td>
<td>38%</td>
<td>74%</td>
<td>191 247</td>
<td>29 406</td>
</tr>
<tr>
<td>Administrative and support service activities</td>
<td>4%</td>
<td>44%</td>
<td>65%</td>
<td>374 185</td>
<td>49 137</td>
</tr>
</tbody>
</table>
Accounting decomposition of aggregate volatility 1/

- $Y_t = \sum_{f \in I_t} y_{f,t}$ a quantity additive over firms $f$ active in year $t$, such as value-added, employment, etc
- $I_t$ set of firms active at time $t$, $I_{t,t-1}$ set of firms active both in $t$ and $t-1$ ("continuers"), $E_t$ set of entrants in $t$, $X_{t-1}$ set of exiters at the end of period $t-1$, thus $I_t = I_{t,t-1} \cup E_t$ and $I_{t-1} = I_{t-1,t} \cup X_{t-1}$
- $\tilde{\gamma} Y_t \equiv \ln(\frac{Y_t}{Y_{t-1}}) = \ln(\sum_{f \in I_t} y_{f,t}) - \ln(\sum_{f \in I_{t-1}} y_{f,t-1})$ growth rate of the aggregate quantity $Y$,
- $\gamma Y_t \equiv \ln(\sum_{f \in I_{t,t-1}} y_{f,t}) - \ln(\sum_{f \in I_{t,t-1}} y_{f,t-1})$ growth rate of the quantity $Y$ over the set of continuers ("intensive margin")
- $\pi_{t,t} \equiv \frac{\sum_{f \in I_{t,t-1}} y_{f,t}}{\sum_{f \in I_t} y_{f,t}}$ share of aggregate $Y_t$ arising from the continuers
- $\pi_{t,t-1} \equiv \frac{\sum_{f \in I_{t,t-1}} y_{f,t-1}}{\sum_{f \in I_{t-1}} y_{f,t-1}}$ share of aggregate $Y_{t-1}$ in year $t-1$ arising from the continuers
- $\lambda_{t} \equiv 1 - \pi_{t,t}$ share of $Y_t$ arising from new entrants and $\lambda_{t,t-1} \equiv 1 - \pi_{t,t-1}$ share of $Y_{t-1}$ arising from exiters, both assumed to be small

$$\tilde{\gamma} Y_t = \gamma Y_t - \ln(\frac{\pi_{t,t}}{\pi_{t,t-1}})$$
Accounting decomposition of aggregate volatility 2/

\[ \tilde{\gamma}_t^Y = \gamma_t^Y - \ln\left(\frac{\pi_t}{\pi_{t-1}}\right) \Rightarrow \text{Var}(\tilde{\gamma}_t^Y) = \text{Var}(\gamma_t^Y) + \text{Var}(\ln\left(\frac{\pi_t}{\pi_{t-1}}\right)) - 2\text{Cov}(\gamma_t^Y; \ln\left(\frac{\pi_t}{\pi_{t-1}}\right)) \]

The variance of the intensive margin of \( Y_t \) can be further decomposed. Let us denote \( \Delta y_{f,t} \equiv y_{f,t} - y_{f,t-1} \), \( \gamma_{f,t}^Y \equiv \frac{\Delta y_{f,t}}{y_{f,t-1}} \) for \( f \in I_{t-1} \) and \( \theta_{f,t-1}^Y = \frac{y_{f,t-1}}{\sum_{k \in I_{t-1}} y_{k,t-1}} \) then:

\[ \gamma_t^Y = \ln\left(\sum_{f \in I_{t-1}} y_{f,t}\right) - \ln\left(\sum_{f \in I_{t-1}} y_{f,t-1}\right) = \ln(1 + \frac{\sum_{f \in I_{t-1}} \Delta y_{f,t}}{\sum_{f \in I_{t-1}} y_{f,t-1}}) \]

\[ = \ln(1 + \sum_{f \in I_{t-1}} \left(\frac{\Delta y_{f,t}}{y_{f,t-1}}\right)\left(\frac{y_{f,t-1}}{\sum_{k \in I_{t-1}} y_{k,t-1}}\right)) \approx \sum_{f \in I_{t-1}} \gamma_{f,t}^Y \theta_{f,t-1}^Y \]

\[ \text{Var}(\gamma_t^Y) \approx \sum_{f \in I_{t-1}} \text{Var}(\gamma_{f,t}^Y \theta_{f,t-1}^Y) + \sum_{f,k \in I_{t-1}, k \neq j} \text{Cov}(\gamma_{f,t}^Y \theta_{f,t-1}^Y; \gamma_{k,t}^Y \theta_{k,t-1}^Y) \]
We can then compute the variance of the growth of aggregate $Y$

$$\text{Var}(\gamma^Y_t) = \text{Var}(\gamma^Y_t) + \text{Var}(\ln(\frac{\pi_{t,t}}{\pi_{t,t-1}})) - 2\text{Cov}(\gamma^Y_t; \ln(\frac{\pi_{t,t}}{\pi_{t,t-1}}))$$

The variance of the intensive margin of $Y_t$ can be further decomposed:

$$\text{Var}(\gamma^Y_t) \approx \sum_{f \in I_{t,t-1}} \text{Var}(\gamma^Y_{f,t} \theta^Y_{f,t-1}) + \sum_{f,k \in I_{t,t-1}, k \neq j} \text{Cov}(\gamma^Y_{f,t} \theta^Y_{f,t-1}; \gamma^Y_{k,t} \theta^Y_{k,t-1})$$

**Remarque 1**

$$\text{Var}(\gamma^Y_{f,t} \theta^Y_{f,t-1}) = \text{Cov}[(\theta^Y_{f,t-1})^2; (\gamma^Y_{f,t})^2] + E[(\theta^Y_{f,t-1})^2]E[(\gamma^Y_{f,t})^2] - (E[\gamma^Y_{f,t} \theta^Y_{f,t-1}])^2$$

The equality $\text{Var}(\gamma^Y_{f,t} \theta^Y_{f,t-1}) \approx (\theta^Y_{f,t-1})^2 \text{Var}[\gamma^Y_{f,t}]$ holds only under the assumption that $\theta^Y_{f,t-1}$ varies little and at a lower frequency than $\gamma^Y_{f,t}$

**Remarque 2**

$$\ln(\frac{\pi_{t,t}}{\pi_{t,t-1}}) = \ln(\frac{1 - \lambda_{t,t}}{1 - \lambda_{t,t-1}}) \approx \ln(1 - \lambda_{t,t} + \lambda_{t,t-1}) \approx \lambda_{t,t-1} - \lambda_{t,t}$$
We can then compute the variance of the growth of aggregate \( Y \)

\[
Var(\gamma^Y_t) = Var(\gamma^Y_t) + Var(\ln(\frac{\pi_{t,t}}{\pi_{t,t-1}})) - 2Cov(\gamma^Y_t; \ln(\frac{\pi_{t,t}}{\pi_{t,t-1}}))
\]

The variance of the intensive margin of \( Y_t \) can be further decomposed:

\[
Var(\gamma^Y_t) \approx \sum_{f \in I_{t,t-1}} Var(\gamma^Y_{f,t} \theta^Y_{f,t-1}) + \sum_{f,k \in I_{t,t-1}, k \neq j} Cov(\gamma^Y_{f,t} \theta^Y_{f,t-1}; \gamma^Y_{k,t} \theta^Y_{k,t-1})
\]

The firm-level variance of \( \gamma^Y_{f,t} \) can be further decomposed:

\[
y_{f,t} = \hat{\beta}_K k_{f,t} + \hat{\beta}_L l_{f,t} + \hat{\beta}_M m_{f,t} + \hat{\omega}_{f,t}
\]

\[
\gamma^Y_{f,t} = \gamma^{inputs}_{f,t} + \gamma^{TFP}_{f,t}
\]

\[
Var(\gamma^Y_{f,t}) \approx Var(\gamma^{inputs}_{f,t}) + Var(\gamma^{TFP}_{f,t}) + Cov(\gamma^{inputs}_{f,t}, \gamma^{TFP}_{f,t})
\]
Real cyclical GDP volatility refers to $\sigma_{PIB cyc}^{Rol. 10}$,

Fundam. Vol. constant sigma to
$$\sqrt{\sum_i \left( \frac{p_{i,t} Q_{i,t}}{p_t Y_t} \right)^2 (\sigma_{i, tfp})^2}$$

Fundam. Vol. 4-y. rol. sigma to
$$\sqrt{\sum_i \left( \frac{p_{i,t} Q_{i,t}}{p_t Y_t} \right)^2 \sigma_{i, t}^{tfp, Rol. 4}}$$
Various firm-level fundamental volatilities

- Domar weights, time-var. vol
- Domar weights, constant. vol
- VA weights, time-var. vol
- VA weights, constant. vol
Main result: overall decrease in firm-level volatility since 2008
- the Eurozone sovereign debt crisis has had no significant impact on our measure of firm-level volatility, although it significantly impacted aggregate volatility
- firm-level volatility from 2008 till 2015 (∼0.14) consistently below its 1990-2008 trend (≤0.14 in 2015)

Figure: Production volatility: aggregated and firm level

M.-B. Khder, R. Monin

To which extent does GDP volatility result from productivity across sectors and firms?
Pervasive downward trend in firm-level volatilities: dispersion of firm-level volatilities
Pervasive downward trend in firm-level volatilities: manufacturing

Volatility production: CN
Volatility production moyenne pondérée des entreprises

M.-B. Khder, R. Monin

To which extent does GDP volatility result from productivity volatility across sectors and firms?
Pervasive downward trend in firm-level volatilities: services

To which extent does GDP volatility result from productivity volatility across sectors and firms?
Pervasive downward trend in firm-level volatilities: continuers only

Anneé | Volatilité des entreprises (CA) échantillon total | Volatilité des entreprises (CA) entreprises pérennes 2005-2010

1990 | 0.12 | 0.14
1995 | 0.18 | 0.16
2000 | 0.20 | 0.18
2005 | 0.14 | 0.16
2010 | 0.12 | 0.14
2015 | 0.10 | 0.12

M.-B. Khder, R. Monin
To which extent does GDP volatility result from productivity?
### Summary statistics: sample

<table>
<thead>
<tr>
<th>Code</th>
<th>Sector</th>
<th>N.obs</th>
<th>N.entr</th>
<th>$g^{production}$</th>
<th>$g^{VA}$</th>
<th>$g^{employment}$</th>
</tr>
</thead>
<tbody>
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<td>A38</td>
<td>food products, beverages and tobacco products</td>
<td>216 963</td>
<td>23 188</td>
<td>1.53</td>
<td>18.14</td>
<td>1.56</td>
</tr>
<tr>
<td>CB</td>
<td>textiles, wearing apparel</td>
<td>110 909</td>
<td>13 281</td>
<td>-0.60</td>
<td>23.63</td>
<td>-1.30</td>
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<td>CC</td>
<td>wood and paper products</td>
<td>196 906</td>
<td>18 557</td>
<td>1.28</td>
<td>19.62</td>
<td>0.54</td>
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<td>CE</td>
<td>chemicals and chemical products</td>
<td>39 042</td>
<td>3 465</td>
<td>2.87</td>
<td>21.91</td>
<td>2.86</td>
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<td>CF</td>
<td>pharmaceutical products</td>
<td>7 257</td>
<td>674</td>
<td>6.32</td>
<td>21.56</td>
<td>6.70</td>
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<tr>
<td>CG</td>
<td>rubber, plastics, non-metallic mineral products</td>
<td>124 715</td>
<td>10 873</td>
<td>2.59</td>
<td>20.67</td>
<td>1.89</td>
</tr>
<tr>
<td>CH</td>
<td>metal products, except machinery and equipment</td>
<td>276 529</td>
<td>22 540</td>
<td>1.85</td>
<td>21.21</td>
<td>1.18</td>
</tr>
<tr>
<td>CI</td>
<td>computer, electronic and optical products</td>
<td>39 315</td>
<td>4 326</td>
<td>7.86</td>
<td>27.12</td>
<td>7.47</td>
</tr>
<tr>
<td>CJ</td>
<td>electrical equipment</td>
<td>31 364</td>
<td>2 956</td>
<td>3.46</td>
<td>23.49</td>
<td>2.80</td>
</tr>
<tr>
<td>CK</td>
<td>machinery and equipment n.e.c.</td>
<td>79 216</td>
<td>7 701</td>
<td>3.31</td>
<td>25.80</td>
<td>2.86</td>
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<tr>
<td>CL</td>
<td>transport equipment</td>
<td>36 407</td>
<td>3 237</td>
<td>2.19</td>
<td>24.41</td>
<td>1.61</td>
</tr>
<tr>
<td>CM</td>
<td>Other manufacturing</td>
<td>270 325</td>
<td>30 247</td>
<td>2.26</td>
<td>24.24</td>
<td>1.73</td>
</tr>
<tr>
<td>FZ</td>
<td>Construction</td>
<td>1 182 235</td>
<td>141 660</td>
<td>0.70</td>
<td>25.34</td>
<td>0.09</td>
</tr>
<tr>
<td>GZ</td>
<td>Wholesale and retail trade; repair of motor vehicles</td>
<td>3 083 677</td>
<td>358 879</td>
<td>1.12</td>
<td>20.22</td>
<td>1.22</td>
</tr>
<tr>
<td>HZ</td>
<td>Transportation and storage</td>
<td>399 293</td>
<td>44 115</td>
<td>2.09</td>
<td>20.54</td>
<td>1.76</td>
</tr>
<tr>
<td>IZ</td>
<td>Accommodation and food service activities</td>
<td>498 866</td>
<td>70 082</td>
<td>-1.11</td>
<td>16.14</td>
<td>-1.17</td>
</tr>
<tr>
<td>JA</td>
<td>Publishing, audiovisual and broadcasting activities</td>
<td>145 036</td>
<td>20 657</td>
<td>2.10</td>
<td>29.84</td>
<td>3.10</td>
</tr>
<tr>
<td>JB</td>
<td>Telecommunications</td>
<td>7 784</td>
<td>1 401</td>
<td>10.24</td>
<td>29.65</td>
<td>11.59</td>
</tr>
<tr>
<td>JC</td>
<td>IT and other information services</td>
<td>137 881</td>
<td>22 046</td>
<td>4.35</td>
<td>29.54</td>
<td>4.95</td>
</tr>
<tr>
<td>LZ</td>
<td>Real estate activities</td>
<td>538 251</td>
<td>79 598</td>
<td>0.28</td>
<td>25.65</td>
<td>0.87</td>
</tr>
<tr>
<td>MA</td>
<td>Legal, accounting, STEMS jobs</td>
<td>703 992</td>
<td>98 514</td>
<td>1.94</td>
<td>25.97</td>
<td>2.11</td>
</tr>
<tr>
<td>MB</td>
<td>Scientific research and development</td>
<td>11 127</td>
<td>1 539</td>
<td>4.56</td>
<td>29.10</td>
<td>5.07</td>
</tr>
<tr>
<td>MC</td>
<td>Other professional, scientific and technical activities</td>
<td>191 247</td>
<td>29 406</td>
<td>0.76</td>
<td>28.56</td>
<td>1.42</td>
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<tr>
<td>NZ</td>
<td>Administrative and support service activities</td>
<td>374 185</td>
<td>49 137</td>
<td>1.97</td>
<td>25.20</td>
<td>2.10</td>
</tr>
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</table>
To which extent does GDP volatility result from productivity volatility across sectors and firms?
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