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

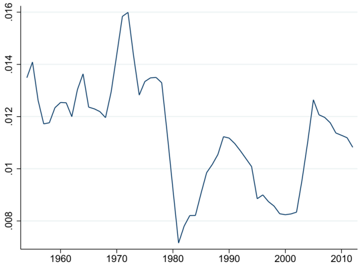


Figure: French GDP volatility

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

- The Great Moderation: Summers (2005), Cabanillas et al. (2008), Stock and Watson (2002) or Blanchard and Simon (2001)
- A more predictable and regular monetary policy? Bernanke (2004), Cabanillas et al. (2008)
- Financial innovation enabling better allocation? Dynan et al. (2006)
- Better organization of production chains? McConnell and Perez-Quiros (2000)
- 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)

Plan

Plan

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** $dlog(A_{i,t})$ **weighted by Domar weights** $\lambda_{i,t}$ defined as the ratio of sector *i*'s nominal output to GDP

$$dlog(Y) = \sum_{i=1}^{N} \lambda_i dlog(A_i)$$

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))

Plan

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** $\sigma_{F,t}$

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

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

Plan

Building the sectoral fundamental volatility

Goal: Estimating the model

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

- GDP volatility $\sigma_{PIB^{cyc}}^{Rol.\,10}$: 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)

$$tfp_{i,t} \equiv lnQ_{i,t} - [\bar{s}_{i,t}^{M} lnM_{i,t} + \bar{s}_{i,t}^{L} lnL_{i,t} + \bar{s}_{i,t}^{K} lnK_{i,t}]$$

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

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_t^X price of $X \in [Q, M, \ldots]$, Sal_t payroll, OS_t operating surplus, $\bar{s}_{i,t}^{X}$ 3-year moving average of $s_{i,t}^{X}$.

Does sectoral fundamental volatility explain GDP volatility?

- The fundamental volatility explains 27-35% of GDP volatility after 1986, but its explanatory power is very low before 1986!

Model	1	2	3	**4**
Regressors		*Dependent variable:* $\sigma_{PIB^{cyc}}^{Rol.\mathbf{10}}$		
$\sqrt{\sum_i (\lambda_{i,t})^2 (\sigma_i^{tfp})^2}$	-0.300	2.157***		
	(0.362)	(0.717)		
$\sqrt{\sum_i (\lambda_{i,t})^2 (\sigma_{i,t}^{tfp,Rol.\mathbf{8}})^2}$			0.0573	0.841***
			(0.164)	**(0.232)**
Constant	0.0186***	-0.0235*	0.0126***	0.00225
	(0.00648)	(0.0124)	(0.00241)	(0.00318)
Estimation starts in	1980	1986	1983	**1986**
Observations	32	26	29	**26**
R-squared	0.022	0.274	0.004	**0.353**

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

- GDP volatility features 3 structural breaks (1984,1998,2004). Once controlling for sectoral fundamental volatility, GDP volatility features only one structural break (1985)

Graphs Baqaee Farhi

Plan

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

Firm-level fundamental volatility and aggregate volatility

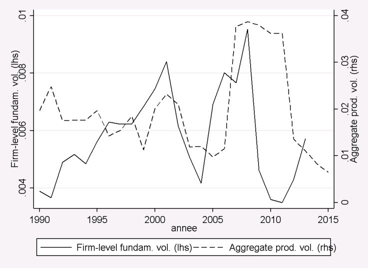


Figure: Firm-level fundamental and aggregate volatility

Firm-level fundamental volatility is based on French tax declarations: databases SUSE and ESANE. Aggregate volatility is based on national accounts data.

- Fundamental volatility indicator σ^{ent}_{Ft} based on firm-level productivities :

$$\sigma^{ent}_{Ft} = \sqrt{\sum_i \left(\frac{S_{it}}{Y_t}\right)^2 \sigma^2_{\omega,i,t}}$$

- 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.

Firm-level fundamental volatilities and aggregate volatility

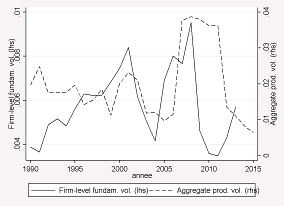
⇒ The change over time in firm-level productivity volatilities should be taken into account

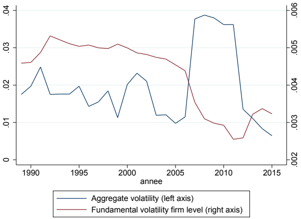
$$\sigma_{Ft}^{\text{ent}} = \sqrt{\sum_i \left(\frac{S_{it}}{Y_t}\right)^2 \sigma^2_{\omega,i,t}}$$

- 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. Graphs

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

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





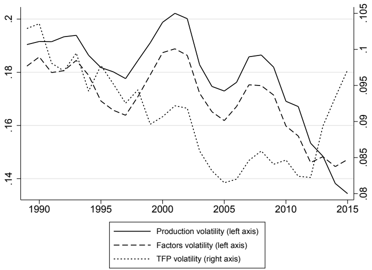
Plan

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):

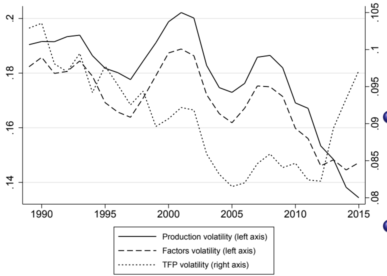
$$v_{it} = \left(\frac{N_{it}}{N_{it}-1}\right)\left(\frac{1}{N_{it}}\sum_{s=t-2}^{t+2} g_{is}^2 - \left(\frac{1}{N_{it}}\sum_{s=t-2}^{t+2} g_{is}\right)^2\right)$$

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

Overall decrease in firm-level production volatility...



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 Firm/agg. vol.
- 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

Pervasive decrease in firm-level production volatility...

TABLE 9 – Average firm-level volatility : 1990-2004 et 2005-2015

Sector	Average volatility 1990-2004	Average volatility 2005-2015	Volatility drop
food products, beverages and tobacco products	0,158	0,143	0,01
textiles, wearing apparel	0,189	0,158	0,03
wood and paper products	0,163	0,150	0,01
chemicals and chemical	0,161	0,181	-0,02
pharmaceutical products	0,175	0,157	0,02
rubber, plastics, non-metallic mineral products	0,143	0,145	0,00
metal products, except machinery and equipment	0,177	0,185	-0,01
computer, electronic and optical products	0,219	0,176	0,04
electrical equipment	0,209	0,159	0,05
machinery and equipment n.e.c.	0,220	0,219	0,00
transport equipment	0,185	0,159	0,03
Other manufacturing	0,210	0,173	0,04
Construction	0,257	0,228	0,03
Wholesale and retail trade ; repair of motor vehicles	0,178	0,156	0,02
Transportation and storage	0,149	0,135	0,01
Accommodation and food service activities	0,156	0,131	0,02
Publishing, audiovisual and broadcasting activities	0,180	0,179	0,00
Telecommunications	0,100	0,111	-0,01
IT and other information services	0,203	0,183	0,02
Real estate activities	0,224	0,186	0,04
Legal, accounting, STEMS jobs	0,221	0,234	-0,01
Scientific research and development	0,178	0,198	-0,02
Other professional, scientific and technical activities	0,261	0,194	0,07
Administrative and support service activities	0,202	0,179	0,02

A pervasive decrease in firm-level production volatility... but an increase in TFP and labor volatility

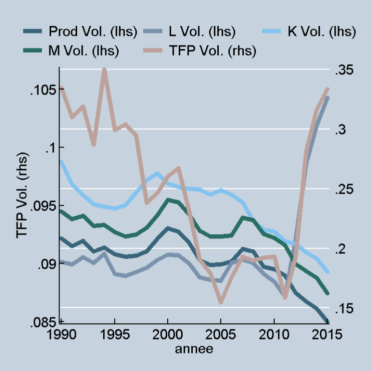


Figure: Firm-level volatility of production, inputs and productivity

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

"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

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, δ_j sectoral fixed effects (firm $i \in$ sector j) and δ_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

	Volatility : total production		Volatility : value added	
	$\widehat{\beta}$	$\widehat{\sigma}$	$\widehat{\beta}$	$\widehat{\sigma}$
Workforce turnover	0.0418***	(0.000372)	0.0532***	(0.000446)
lagged	0.0431***	(0.000371)	0.0597***	(0.000445)
Investment rate	-0.000763***	(0.0000485)	-0.0000266	(0.0000581)
lagged	0.0000494	(0.0000422)	0.00354***	(0.0000507)
Export status	0.0105***	(0.000218)	0.0145***	(0.000261)
lagged	0.00830***	(0.000218)	0.0137***	(0.000261)
Export rate	0.0420***	(0.000728)	0.0442***	(0.000873)
lagged	0.0349***	(0.000728)	0.0361***	(0.000873)
TFP growth	0.0184***	(0.000469)	0.0218***	(0.000563)
Belongs to a group	0.00832***	(0.000132)	0.0184***	(0.000159)
Geographical scope				
2 departements	0.00866***	(0.000297)	0.0144***	(0.000356)
>2 departements	0.00476***	(0.000438)	0.0150***	(0.000525)
Average workforce				
[10-20]	-0.0230***	(0.000157)	-0.0436***	(0.000188)
[20-50]	-0.0341***	(0.000193)	-0.0623***	(0.000231)
[50-250]	-0.0465***	(0.000287)	-0.0835***	(0.000344)
[>250]	-0.0724***	(0.000579)	-0.117***	(0.000694)
Last year in sample	0.0237***	(0.000218)	0.0385***	(0.000261)
N	5395850		5395850	
adj. R-sq	0.095		0.072	

Source : SUSE - ESANE - DADS - LIFI.
Scope : scope of study, 1994-2015 Estimation with sector and year fixed-effects.
Standard errors in parenthesis écarts-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

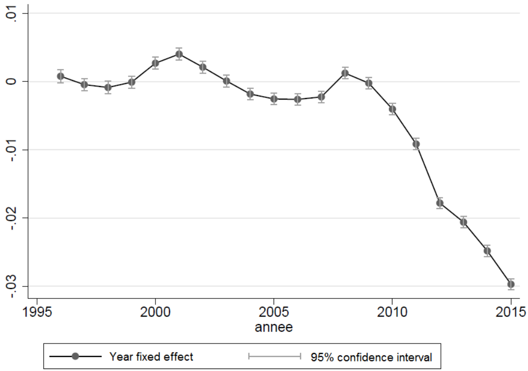


Figure: Regression year fixed effects

Does granularity explain aggregate volatility?

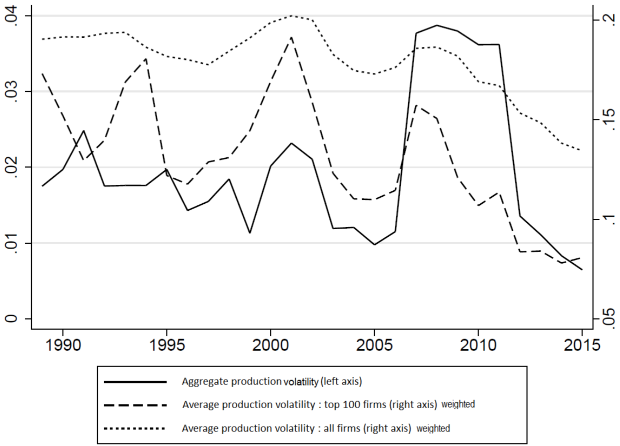


Figure: Volatility of large firms, of all firms and aggregate production volatility

Plan

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

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

- (+) 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 beginnning 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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Baqaee and Farhi (2017)'s improvement on Hulten's model

If the economy is subjected to several simultaneous sectoral technological shocks $(dlog(A_i))_{i=1}^{N}$ 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:

$$dlog(Y) = \sum_i \lambda_i dlogA_i$$
$$+ \frac{1}{2} \sum_i \sum_{j \neq i} [\frac{\lambda_i}{\xi} \sum_{k \neq j} \lambda_k (1 - \frac{1}{\rho_{j,k}}) + \lambda_i \frac{dlog\xi}{dlogA_j} - \lambda_i (1 - \frac{1}{\rho_{j,i}})] dlogA_i dlogA_j$$
$$+ N \sum_{i=1}^{N} \lambda_i (dlogA_i)^2$$

where:
• λ_i refers to the Domar weight of sector i,
• ξ, which is defined as the sum of Domar weigths 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.

Hulten Macro results

Baqaee 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
- Δy_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
- Δtfp_i the growth of sector i's productivity.

Baqaee and Farhi (2017)'s improvement on Hulten's model

Model

Table 3 – Influence of second-order sectoral productivity shocks on GDP growth

VARIABLES	benchmark	2	3	4	5	6
$\sum_i(\frac{p^Q_{i,t}Q_{i,t}}{p^Y_t Y_t})\Delta tfp_i$	0.00937	0.132*	0.140**	0.126*	0.143*	0.425***
	(0.0385)	(0.0655)	(0.0681)	(0.0682)	(0.0729)	(0.0658)
$(\Delta tfp_{C2,t})^2$			-0.0183	0.00388	0.0245	
			(0.0363)	(0.0396)	(0.0497)	
$(\Delta tfp_{FZ,t})^2$					-0.708	
					(1.012)	
$(\Delta tfp_{GZ,t})^2$						
$(\Delta tfp_{HZ,t})^2$						
$(\Delta tfp_{KZ,t})^2$		-0.917**	-0.933**	-0.722	-0.743	-0.629
		(0.408)	(0.414)	(0.439)	(0.444)	(0.403)
$(\Delta tfp_{LZ,t})^2$				-0.883	-0.878	
				(0.671)	(0.677)	
Constant	-0.00222	-0.00354	-0.00320	-0.00193	-0.00191	0.0133**
	(0.00317)	(0.00305)	(0.00316)	(0.00327)	(0.00330)	(0.00251)
Observations	36	36	36	36	36	29
R-squared	0.002	0.134	0.141	0.187	0.200	0.652

Dependent Variable : Δy^{cyc}_t

Estimation period: 1979-2014 (benchmark–5); 1986-2014 (6)

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

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). ω_{it} is the TFP, ϵ_{it} the error term.
- Levinsohn and Petrin (2003) estimation: correction of the bias created by the simultaneity between productivity (ω_{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 ω_{it}, strictly increasing with the productivity ω_{it}.
- Two step-estimation: (1) use a control function (second order polynomial) of k and m to identify β_L and β_M, under the hypothesis that the capital stock k cannot immediately adjust to contemporaneous productivity shock ω_{it}, and that the contemporaneous productivity shock ω_{it} is independent from intermediate consumption at time $t-1$ (2) a proxy of ω_{it} is used to recover the capital coefficient β_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.

Computing firm-level TFP 3/3

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Table 8 – Coefficients from Levinsohn Petrin estimation

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

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 $I_t = I_{t,t-1} \bigcup E_t$ and $I_{t-1} = I_{t,t-1} \bigcup X_{t-1}$
- $\tilde{\gamma}_t^Y \equiv ln(\frac{Y_t}{Y_{t-1}}) = ln(\sum_{f \in I_t} y_{f,t}) - ln(\sum_{f \in I_{t-1}} y_{f,t-1})$ growth rate of the aggregate quantity Y,
- $\gamma_t^Y \equiv ln(\sum_{f \in I_{t,t-1}} y_{f,t}) - ln(\sum_{f \in I_{t,t-1}} y_{f,t-1})$ 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
- $\lambda_{t,t} \equiv 1 - \pi_{t,t}$ 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

$$\tilde{\gamma}_t^Y = \gamma_t^Y - ln(\frac{\pi_{t,t}}{\pi_{t,t-1}})$$

Accounting decomposition of aggregate volatility 2/

$$\tilde{\gamma}_t^Y = \gamma_t^Y - ln(\frac{\pi_{t,t}}{\pi_{t,t-1}}) \Rightarrow Var(\tilde{\gamma}_t^Y) = Var(\gamma_t^Y) + Var(ln(\frac{\pi_{t,t}}{\pi_{t,t-1}})) - 2Cov(\gamma_t^Y; ln(\frac{\pi_{t,t}}{\pi_{t,t-1}}))$$

- 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 $f \in I_{t,t-1}$ and $\theta_{f,t-1}^Y \equiv \frac{y_{f,t-1}}{\sum_{k \in I_{t,t-1}} y_{k,t-1}}$ then:

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

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

$$Var(\gamma_t^Y) \approx \sum_{f \in I_{t,t-1}} Var(\gamma_{f,t}^Y \theta_{f,t-1}^Y) + \sum_{f,k \in I_{t,t-1}, \quad k \neq j} Cov(\gamma_{f,t}^Y \theta_{f,t-1}^Y; \gamma_{k,t}^Y \theta_{k,t-1}^Y)$$

Accounting decomposition of aggregate volatility 3/

- We can then compute the variance of the growth of aggregate Y

$$Var(\tilde{\gamma}_t^Y) = Var(\gamma_t^Y) + Var(ln(\frac{\pi_{t,t}}{\pi_{t,t-1}})) - 2Cov(\gamma_t^Y; ln(\frac{\pi_{t,t}}{\pi_{t,t-1}}))$$

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

$$Var(\gamma_t^Y) \approx \sum_{f \in I_{t,t-1}} Var(\gamma_{f,t}^Y \theta_{f,t-1}^Y) + \sum_{f,k \in I_{t,t-1}, \quad k \neq j} Cov(\gamma_{f,t}^Y \theta_{f,t-1}^Y; \gamma_{k,t}^Y \theta_{k,t-1}^Y)$$

- Remarque 1

$$Var(\gamma_{f,t}^Y \theta_{f,t-1}^Y) = Cov[(\theta_{f,t-1}^Y)^2; (\gamma_{f,t}^Y)^2] + E[(\theta_{f,t-1}^Y)^2]E[(\gamma_{f,t}^Y)^2] - (E[\gamma_{f,t}^Y \theta_{f,t-1}^Y])^2$$

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

- Remarque 2

$$ln(\frac{\pi_{t,t}}{\pi_{t,t-1}}) = ln(\frac{1-\lambda_{t,t}}{1-\lambda_{t,t-1}}) \approx ln(1 - \lambda_{t,t} + \lambda_{t,t-1}) \approx \lambda_{t,t-1} - \lambda_{t,t}$$

Accounting decomposition of aggregate volatility 4/

- We can then compute the variance of the growth of aggregate Y

$$Var(\tilde{\gamma}_t^Y) = Var(\gamma_t^Y) + Var(ln(\frac{\pi_{t,t}}{\pi_{t,t-1}})) - 2Cov(\gamma_t^Y; ln(\frac{\pi_{t,t}}{\pi_{t,t-1}}))$$

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

$$Var(\gamma_t^Y) \approx \sum_{f \in I_{t,t-1}} Var(\gamma_{f,t}^Y \theta_{f,t-1}^Y) + \sum_{f,k \in I_{t,t-1}, \quad k \neq j} Cov(\gamma_{f,t}^Y \theta_{f,t-1}^Y; \gamma_{k,t}^Y \theta_{k,t-1}^Y)$$

- The firm-level variance of $\gamma_{f,t}^Y$ can be further decomposed :

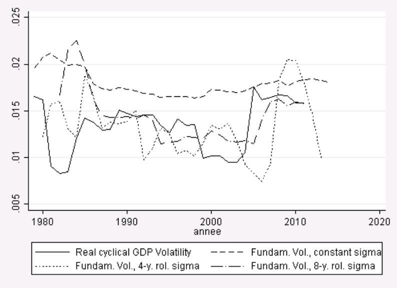
$$y_{f,t} = \underbrace{\widehat{\beta}_K k_{f,t} + \widehat{\beta}_L l_{f,t} + \widehat{\beta}_M m_{f,t}}_{\text{factors}} + \underbrace{\widehat{\omega}_{f,t}}_{\text{TFP}}$$

$$\gamma_{f,t}^Y = \gamma_{f,t}^{inputs} + \gamma_{f,t}^{TFP}$$

$$Var(\gamma_{f,t}^Y) \approx Var(\gamma_{f,t}^{inputs}) + Var(\gamma_{f,t}^{TFP}) + Cov(\gamma_{f,t}^{inputs}; \gamma_{f,t}^{TFP})$$

Accounting

GDP and sectoral fundamental volatilities



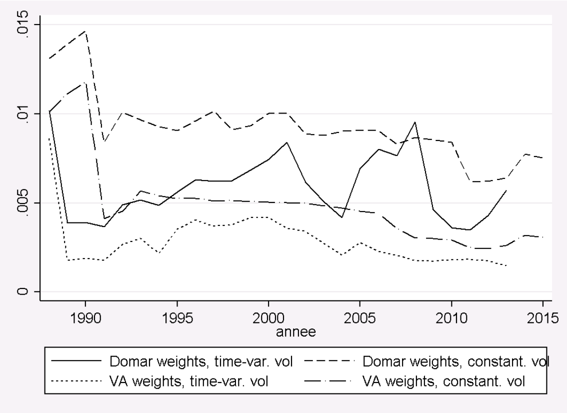
Real cyclical GDP volatility refers to $\sigma^{Rol.\mathbf{10}}_{PIB^{cyc}}$,

Fundam. Vol. constant sigma to $\sqrt{\sum_i (\frac{p^Q_{i,t} Q_{i,t}}{p^Y_t Y_t})^2 (\sigma^{tfp}_i)^2}$,

Fundam. Vol. 4-y. rol. sigma to $\sqrt{\sum_i (\frac{p^Q_{i,t} Q_{i,t}}{p^Y_t Y_t})^2 \sigma^{tfp,Rol.\mathbf{4}}_{i,t}}$

Macro results

Various firm-level fundamental volatilities



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Firm-level production volatility and aggregate volatility

Main result: Back

- **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 ($\lesssim 0.14$ in 2015)

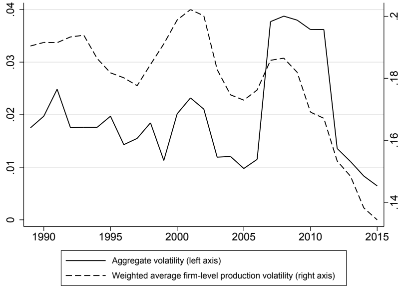
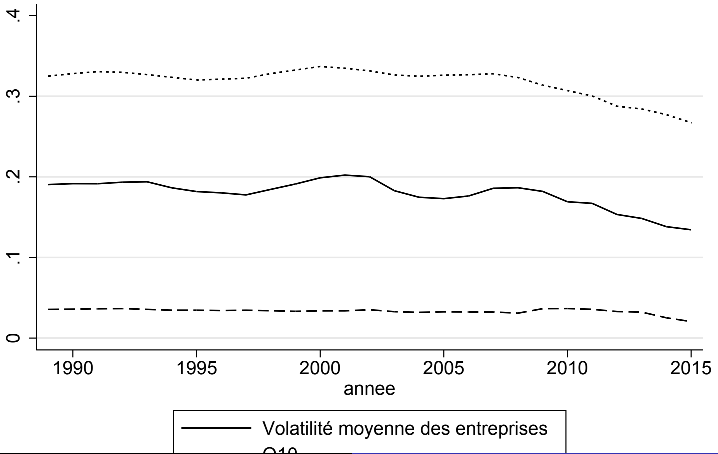
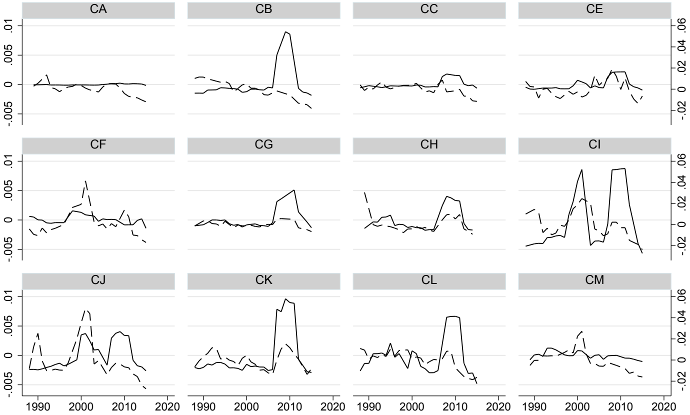


Figure: Production volatility : aggregated and firm level

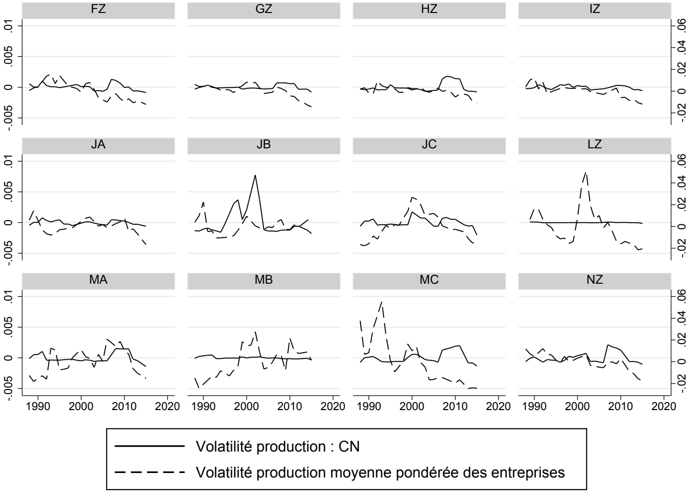
Pervasive downward trend in firm-level volatilities: dispersion of firm-level volatilties



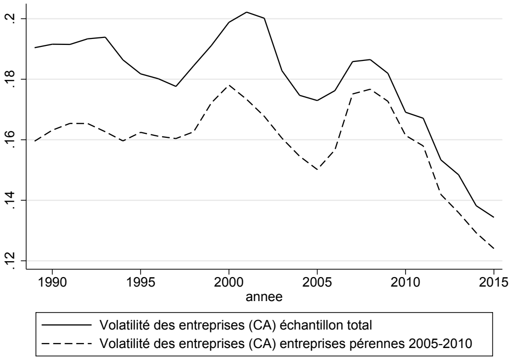
Pervasive downward trend in firm-level volatilities: manufacturing



Pervasive downward trend in firm-level volatilities: services



Pervasive downward trend in firm-level volatilities: continuers only



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Summary statistics: sample

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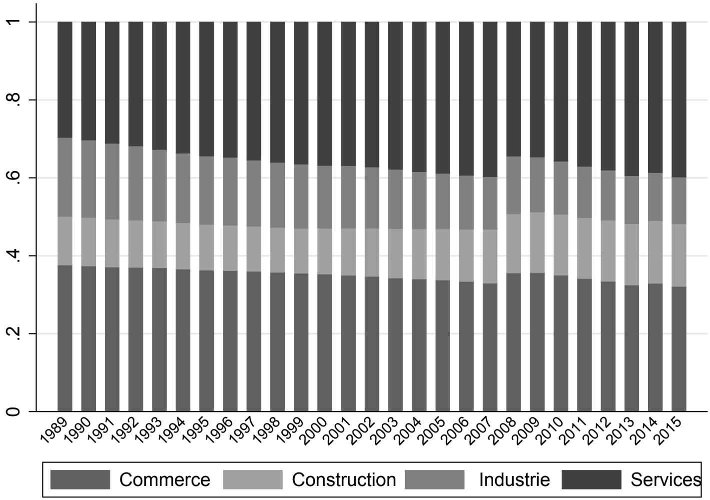
Code	Sector	N.obs	N.entr	$g^{production}$		g^{VA}		$g^{emplyment}$	
A38				g	σ_g	g	σ_g	g	σ_g
CA	food products, beverages and tobacco products	216 963	23 188	1,53	18,14	1,56	24,03	0,65	20,63
CB	textiles, wearing apparel	110 959	13 281	-0,60	23,63	-1,30	29,91	-1,56	22,70
CC	wood and paper products	196 906	18 557	1,28	19,62	0,54	25,17	-0,36	19,63
CE	chemicals and chemical products	39 042	3 465	2,87	21,91	2,86	28,91	1,01	20,75
CF	pharmaceutical products	7 257	674	6,32	21,56	6,70	29,60	2,37	20,34
CG	rubber, plastics, non-metallic mineral products	124 715	10 873	2,59	20,67	1,89	25,79	0,46	19,06
CH	metal products, except machinery and equipment	276 529	22 540	1,85	21,21	1,18	24,41	0,46	18,30
CI	computer, electronic and optical products	39 315	4 326	7,86	27,12	7,47	31,40	1,34	22,60
CJ	electrical equipment	31 364	2 956	3,46	23,49	2,80	27,21	0,55	20,23
CK	machinery and equipment n.e.c.	79 216	7 701	3,31	25,80	2,86	27,96	0,71	19,40
CL	transport equipment	36 407	3 237	2,19	24,41	1,61	27,08	0,73	18,93
CM	Other manufacturing	270 325	30 247	2,26	24,24	1,73	27,57	0,25	21,40
FZ	Construction	1 182 235	141 660	0,70	25,34	0,09	26,48	0,45	21,51
GZ	Wholesale and retail trade ; repair of motor vehicles	3 083 677	358 879	1,12	20,22	1,22	27,08	0,44	21,93
HZ	Transportation and storage	399 293	44 115	2,09	20,54	1,76	25,86	1,63	22,70
IZ	Accommodation and food service activities	498 866	70 082	-1,11	16,14	-1,17	23,46	-0,15	25,24
JA	Publishing, audiovisual and broadcasting activities	145 036	20 657	2,10	29,84	3,10	37,71	0,76	30,76
JB	Telecommunications	7 784	1 401	10,24	29,05	11,59	36,96	3,46	31,25
JC	IT and other information services	137 881	22 046	4,35	29,54	4,95	34,66	2,97	27,74
LZ	Real estate activities	538 251	79 598	0,28	25,65	0,87	32,51	0,20	21,75
MA	Legal, accounting, STEMS jobs	703 992	98 514	1,94	25,97	2,11	31,03	1,25	25,86
MB	Scientific research and development	11 127	1 539	4,56	29,10	5,07	35,86	2,29	26,28
MC	Other professional, scientific and technical activities	191 247	29 406	0,76	28,56	1,42	33,95	0,67	27,35
NZ	Administrative and support service activities	374 185	49 137	1,97	25,20	2,10	30,11	1,46	28,34

Sample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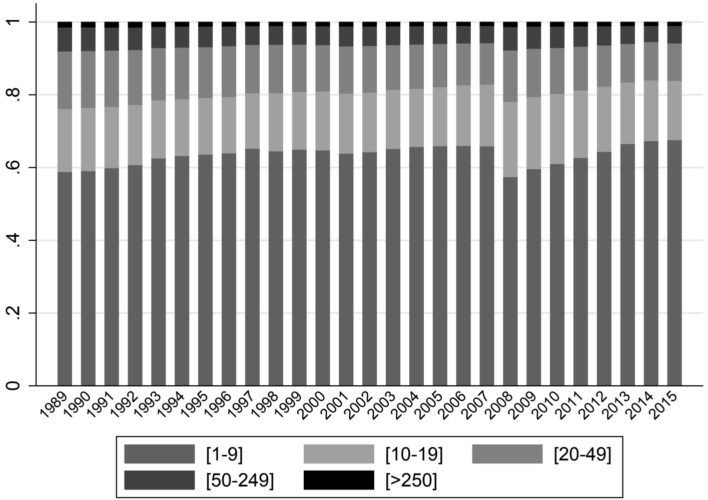
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