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The granularity of the manufacturing sector : insights from a developing economy

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Abstract

The paper examines the granularity of the manufacturing sector as a key determinant of aggregate productivity in the context of a developing economy. We investigate this hypothesis in the case of Morocco, an economy that has yet to rich the emergent market status. Our findings support that the large firms are significant drivers of fluctuations within the manufacturing sector, thereby lending support to the notion that concentration, brought about by high entry costs and institutional constraints, has far-reaching consequences. Specifically, idiosyncratic shocks, experienced by large firms, explain more than one-third of the aggregate volatility in the sector. Our robustness checks lend credence that firm-level shocks are idiosyncratic and serve as valuable predictors of fluctuations within the manufacturing sector.

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1. Introduction

According to the large numbers law, the mainstream macroeconomics has assumed, since Lucas (1977), that firm-level idiosyncratic shocks contribute marginally to aggregate fluctuations. The seminal paper of Gabaix (2011) challenged this "diversification argument", and introduced the granular hypothesis according to which idiosyncratic shocks to large firms (grains) have the potential to generate nontrivial aggregate fluctuation. He observed that the firm-size distribution is fat-tailed, and documented that the large 100 firms have a significant impact on the business cycle fluctuations in the United States of America. This hypothesis doesn't neglect the role of aggregate shocks, such as monetary or fiscal shocks, in driving the business cycle; it simply means that the behavior of large firms is important too if not the major driver.

Furthermore, Gabaix (2011) postulated that granular effects are likely to be stronger outside the United States, as the United States is more diversified than most other countries. The ongoing literature demonstrates the importance of this intuition (e.g. di Giovanni et al. 2014, Ebeke and Eklou 2017, Fornaro and Luomaranta 2018, and Miranda-Pinto and Shen 2019). More specifically, this approach is useful for thinking about the fluctuations of other economic aggregates than productivity such as exports, imports, investment or employment (e.g. del Rosal 2013, Karasik et al. 2016, Lucio et al. 2017).

In this paper, we investigate the granularity of the Moroccan manufacturing sector. Several papers have documented the importance of the largest manufacturing firms in Germany (Wagner 2012), Russia (Popova 2019) and Italy (Gnocato and Rondinelli 2018).To the best of our knowledge, this contribution is the first research that focuses on a Developing but not yet Emerging Industrial Economy[1]. In such countries, the manufacturing firms are expected to be relatively concentrated, as a result of high entry costs and institutional constraints (Tybout 2000).

This paper is organized as follows. The data and its features are presented in section 2. We assess the granularity of the manufactory sector in section 3. We check the results' robustness in section 4. Section 5 concludes.

2. Data and methodology

To perform this investigation, we use the annual company-level database of Moroccan manufacturing companies covering the period from 1990 to 2013. This database is produced by the Moroccan Ministry of Industry and Trade. We removed the units that suffer from data issues, ending up with 1073 firms for which data are available for the entire span. This sample is classified into five industries: agri-food industry; Manufacture of textiles and leather;

[1]According to UNIDO's classification (Upadhyaya 2013).

Chemical industry; Electric and electronic industry; and, finally, metallic and mechanic industry. This subdivision is based on the section D[2] of the International Standard Industrial Classification (Revision 3.1). We exclude the oil industry as is widely done in the literature because the sharp fluctuations in world energy prices make its sales a poor indicator of productivity.

As documented by (Gabaix 2011), the granular hypothesis require that the Herfindahl measure or the standard deviation of the firm's size are sufficiently large. In particular, he determines the condition where the shocks originating from sizable firms may not average out and, hence, generate an aggregate effect. If we assume *a priori* that the distribution of a firm's size S follows a power-law distribution (PL hereafter) i.e.:

$$P(S > s) = as^{-\theta} \text{ for } s > a^{1/\theta} \quad with \quad \theta \geq 0 \tag{1}$$

Then, the firm-size volatility σ_i has a non-neglected[3] impact on aggregate volatility σ_Y if $\theta < 2$. The diversification argument, whereby the micro-level shocks average out, holds only when $\theta \geq 2$.

The nature of the firm's size, especially when it follows a PL distribution, is a necessary condition for granularity. We consider it is relevant, according to the literature, to check this condition for Moroccan data before testing the granularity hypothesis.

To check this condition we estimate the PL's parameter and test the PL's hypothesis. The estimation does not allow us to be sure of whether the data follow a PL distribution. We follow the approach of Clauset et al. (2009) rather than the semi-parametric method developed by Gabaix and Ibragimov (2011) and Gabaix (2009)[4]. For that, we redefine a PL distribution, in formula (1), by using the density function:

$$P(S = s) = \frac{\theta}{s_0}\left(\frac{s}{s_0}\right)^{-(\theta+1)} = \frac{\alpha-1}{s_0}\left(\frac{s}{s_0}\right)^{-\alpha} \; where \;\; \alpha = 1 + \theta \tag{2}$$

The maximum likelihood estimator of the PL's coefficient θ is driven directly from:

$$\hat{\alpha} = 1 + \mathrm{n}\left[\sum_{\mathrm{i}=1}^{\mathrm{n}} \ln\left(\frac{s_i}{s_{min}}\right)\right]^{-1} \quad , s_i > s_{min} \tag{3}$$

Where the lower bound s_{min} is determined by minimizing the "distance" between the power-law model and the empirical data.

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[2] Ranging from division 15 to 37.

[3] In an economy populated by N firms, if we assume that each firm i is affected by an $i.i.d$ production shock (with unit variance) and have the same firm-level volatility ($\sigma_i = \sigma$), than aggregate volatility σ_Y can be approximated by $\sigma_Y = \mu * h * \sigma$ where h is the Herfindahl index and μ the productivity multiplier or factor usage (Gabaix 2011).

[4] The fondamental caveat of this method is that the number of firms used in the estimation follows the coventional cutoff rule (5%) in the littarature.

To test the power-law null hypothesis, we apply a Goodness-of-Fit test, based on Bootstrap sampling. The test is based on the measurement of the distance between the distribution of the empirical data and a hypothesized model. The plausibility of the hypothesis is gauged by the p-value. If p is large, then the difference between the empirical data and the model can be attributed to statistical fluctuations alone; if it is small, the model is not a plausible fit for the data. Thus, the null hypothesis can only be rejected if p exceeds the chosen threshold.

The nature of the firm's size, and the special case of the PL distribution, is a necessary but not sufficient conditions for the granularity. To check whether the top manufacturing firms' shocks have a significant impact on the manufacturing sector, the methodology we used closely follows (Gabaix 2011). We construct the granular residual Γ_t, in year t, as the summary measure of idiosyncratic labour productivity shocks $\varepsilon_{i,t}$ to the top K firms:

$$\Gamma_t = \sum_{i=1}^{K} \frac{S_{i,t-1}}{Y_{t-1}} \left(g_{i,t} - \bar{g}_t\right) = \sum_{i=1}^{K} w_{i,t-1}\, \varepsilon_{i,t} \tag{4}$$

where $S_{i,t-1}$ is the sale of firm i, Y_{t-1} is the manufacturing value-added (MVA) and $w_{i,t-1}$ is the weight of firm i (Domar's weight). The labour productivity growth rate is defined as $g_{i,t} = z_{i,t} - z_{i,t-1}$, where $z_{i,t}$is the logarithm of the real sale $S_{i,t}$ per worker. The idiosyncratic labour productivity shock is captured by $\varepsilon_{i,t} = g_{i,t} - \bar{g}_t$. The $\bar{g}_t$, the mean of $g_{i,t}$ over the top Q firms, is the proxy of aggregate macroeconomic shock that affect all firms.

In the second specification, we control for sectoral shock, where the mean $\bar{g}_t^I$ is computed for each predefined five industries:

$$\Gamma_t^I = \sum_{i=1}^{K} \frac{S_{i,t-1}}{Y_{t-1}} \left(g_{i,t} - \bar{g}_t^I\right) \equiv \sum_{i=1}^{K} w_{i,t-1}\, \varepsilon_{i,t}^I \tag{5}$$

The test of the granular hypothesis is performed by regressing the year-to-year growth g_t^Y of the real MVA, on this granular residual and its lags:

$$g_t^Y = \beta_0 + \beta(L)\Gamma_t \quad + u_t \tag{6.a}$$

$$g_t^Y = \ \beta_0 + \beta(L)\Gamma_t^I + u_t^I \tag{6.b}$$

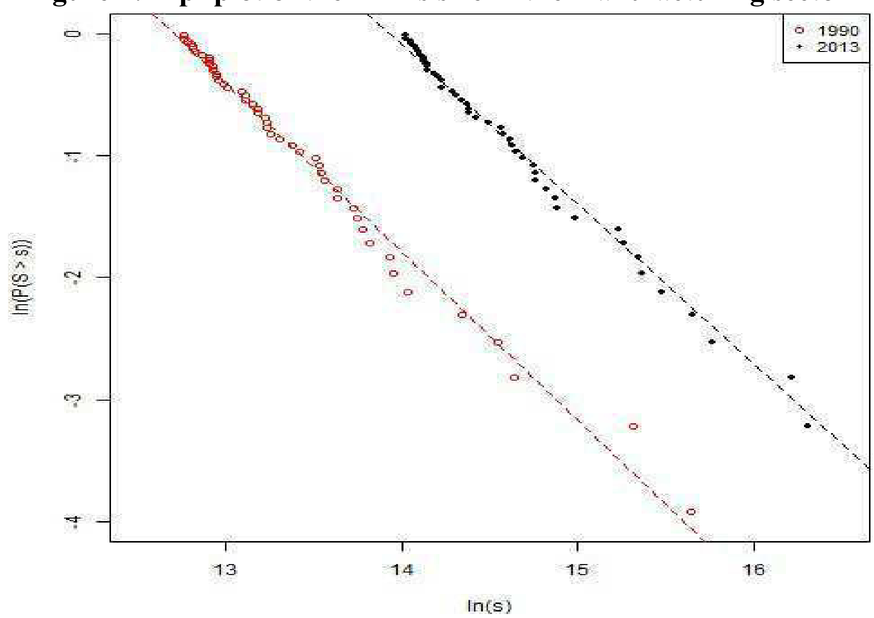
where $u_t$and u_t^I are the error terms and[5] $\beta(L) = \ \beta_1 + \beta_2 L$. We evaluate the explanatory power of the granular residual using the adjusted-R^2. The aggregate shocks only matter if the latter is equal to zero.

[5] We limit our choice to the first lag according to the large strand of literature.

3. Results

As discussed in the previous section, we check, in the first step, the nature of size's firm distribution. Figure 1, where we visualize the size's countercumulative function of the top firms (right tail) in a sample of two years, shows that the PL distribution fits substantially well the firm's size (the logarithm of Eq. 1 leads a linear relation between $\log(P(S > s))$ and $\log(s)$).

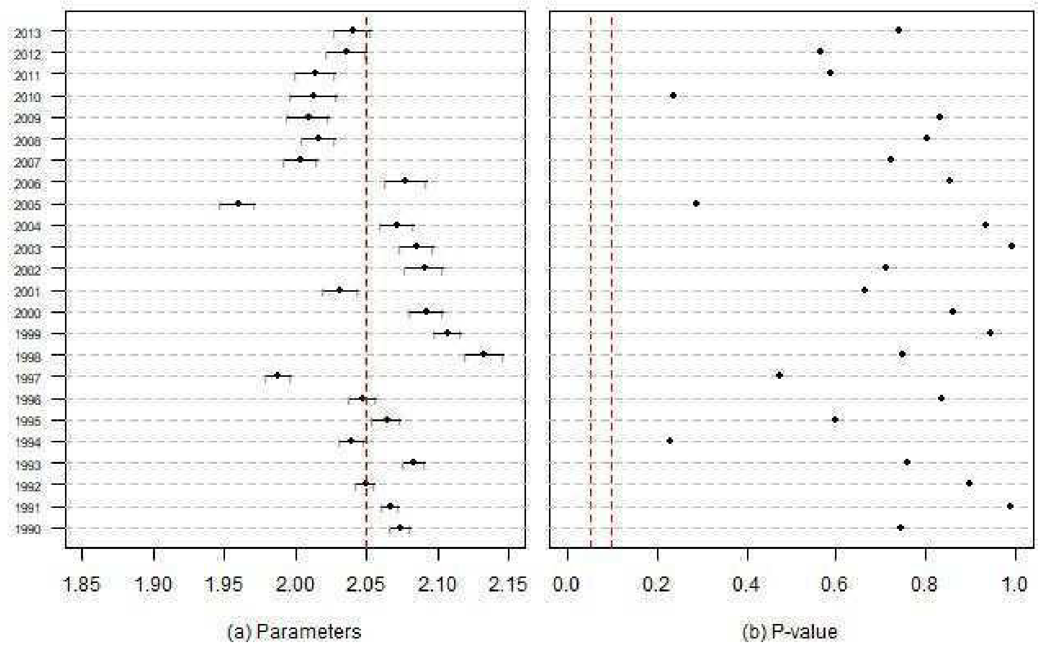
Figure 1: Zipf plot of the firm's size in the manufacturing sector



Note: the figure plots, for the top firms during two years, the countercumulative function (in logarithm) of the firm's size in function of the firm's sale (in logarithm).

The estimation of the power's parameter leads to a mean estimate of $\hat{\alpha} = 2.05$ and thus $\hat{\theta} = \hat{\alpha} - 1 = 1.05$. These estimates are robust because the related standard deviation is $\sigma_{\hat{\alpha}} = 0.03$ (see additional material). The power distribution hypothesis cannot be rejected, as the $p - value$ is systematically greater than the 10% risk. It follows that we can conclude that the size of the manufacturing firms can be well represented by a Zipf distribution. This conclusion is furthermore robust over time highlighting the potential evidence of a granular hypothesis in the manufacturing sector, which we examine in the next section.

Figure 2: PL coefficients and null-hypothesis tests



Note: The first graph shows the estimated values of the PL parameters (points) based on the (Clauset, Shalizi, and Newman 2009) method. The segments between the whiskers indicate the intervals of +/- one standard deviation. The red dashed line is the mean of PL parameters over the whole period 2001-2018. The second graph gives the $p - value$ for the PL hypothesis, derived from simulations of 1000 samples, for each year, using the Bootstrap method. The two red dashed lines correspond to the 5% and 10% risk and delimit the rejection zones.

In the second step, the regression approach is done by choosing $K = Q = 100$, following the conventional scheme. The regression results (Table 1, columns 1 to 4) support the granular hypothesis. The contemporaneous granular residual is positive and statistically significant at the 1% level. Moreover, its value, located around 0.19, does not depend on demeaning. The contemporaneous granular residual account for 30% of the aggregate fluctuations of MVA. In contrast, the granular residual's first lag does not have the expected sign and is statistically non-significant. Hence, these results support the granular hypothesis in Moroccan manufacture. However, we should validate it by a robustness check against several issues. That is what we develop in the next section.

Table 1: The granularity of the Moroccan Manufacturing sector

K	$K = 100$				$K = K_{Inner} = 45$			
Equations	**(6.a)**		**(6.b)**		**(6.a)**		**(6.b)**	
Models	**1**	**3**	**2**	**4**	**5**	**6**	**7**	**8**
β_0	0.0262***	0.0254***	0.0266***	0.0257***	0.0259***	0.0252***	0.0263***	0.0255***
	(0.0043)	(0.0047)	(0.0043)	(0.0046)	(0.0042)	(0.0047)	(0.0042)	(0.0047)
Γ_t	0.1874***	0.1959***			0.1960***	0.2032***		
	(0.0569)	(0.0654)			(0.0574)	(0.0674)		
Γ_{t-1}		-0.0252				-0.0135		
		(0.0627)				(0.0655)		
Γ_t^I			0.1881***	0.1989***			0.1967***	0.2062***
			(0.0577)	(0.0657)			(0.0581)	(0.0673)
Γ_{t-1}^I				-0.0184				-0.0080
				(0.0631)				(0.0655)
R^2	0.3408	0.3837	0.3361	0.3741	0.3568	0.3854	0.3532	0.3797
Adjusted R^2	0.3094	0.3188	0.3045	0.3082	0.3262	0.3207	0.3225	0.3144
# Obs.	23	22	23	22	23	22	23	22

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

Note: The table presents the OLS coefficients from the Eq. (6.a) and (6.b) of the granularity for the fluctuation in the manufacturing sector. Models 1 to 4 were estimated with the 100 largest firms. The others (models 5 to 8) are estimated with only the 45 largest firms. The latter choice comes from the inner determination method of Blanco-Arroyo et al. (2018). The sectoral demeaning is based on the five industries previously specified.

To confirm the robustness of the presented results, we modify the number of sizable firms (K) and check whether the calculated firm-level shock are idiosyncratic.

The choice of k (number of the grains) is previously set up conventionally but is still arbitrary. To check the robustness of the results to different values of K, we look for the inner granular size following the endogenous determination approach suggested by Blanco-Arroyo et al. (2018). The basic idea is to compare the explanatory power of the weighted granular residual as described previously (eq. 6) and an equal-weighted one (benchmark) for a different range of firms. Following the diversification argument, the contribution of idiosyncratic shocks to aggregate fluctuation in the benchmark model is expected to be marginal.

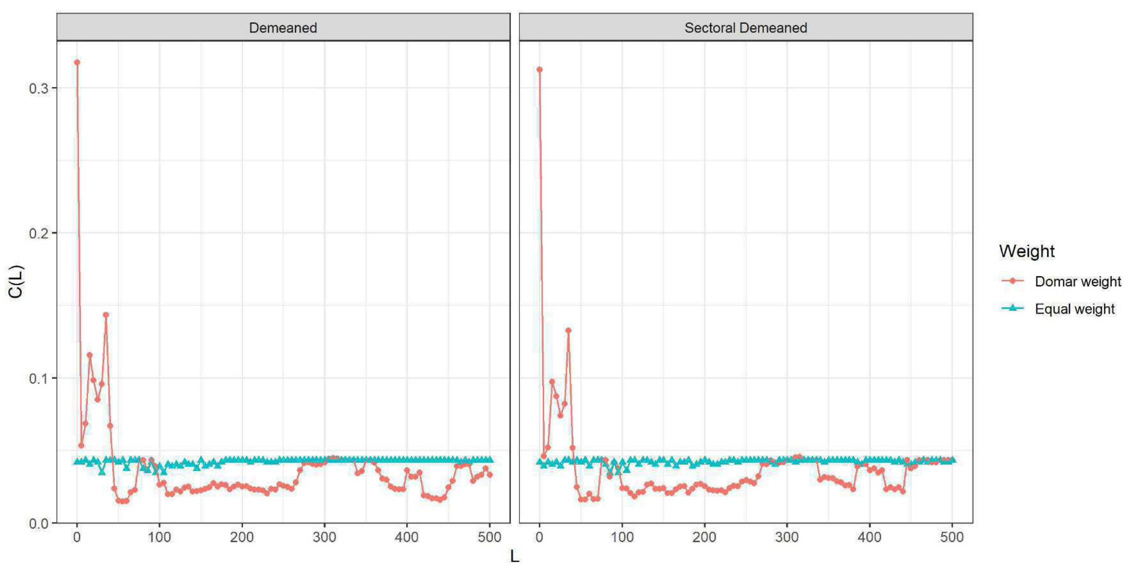
Formally, to validate that the L large firms are granular, we compare the benchmark granular residuals $\Gamma_t^{L,E} = \sum_{i=L+1}^{L+K} \frac{S_{*,t-1}}{Y_{t-1}} (g_{i,t} - \bar{g}_t)$ with the weighted one $\Gamma_t^{L,D} = \sum_{i=L+1}^{L+K} \frac{S_{i,t-1}}{Y_{t-1}} (g_{i,t} - \bar{g}_t)$. The equal weight $S_{*,t-1}$ is set equal to the smallest firm[6] and $\bar{g}_t = \left(\sum_{i=L+1}^{Q} g_{i,t}\right)/(Q - L)$. Hence, we then estimate the models (6) for a set of K (10 to 500 with the incremental step of 10). The explanatory power is defined as the average of the adjusted R²: $C_L^E = \overline{R_E^2(K,L)}$

[6] We choose the mean of the last firm's decile.

and $C_L^D = \overline{R_D^2(K,L)}$. The inner granular size $K^*$is equal to the largest L satisfying $C_L^D > C_L^E$. Figure 3 gives the results of this endogenous determination. We can distinguish that *L=45* is the last point where the weighted curve C_L^D is higher than the unweighted curve, regardless of the demeaned control. Hence, in the Moroccan case, the number of grains is largely smaller than the conventional one.

The re-estimation of the models (6) (table1, columns 5 to 8) with this endogenous number of grains ($K_{Inner} = 45$) indicates that the granular residual better explains the aggregate fluctuation in the manufactory sector, accounting for around 32%. Moreover, the contemporaneous granular residual still have the same precision and the contemporaneous parameter's reached 0.20. it is worthwhile to note that this parameter is small compared to what we found in the related literature. In terms of economics, this suggests that the productivity multiplier (μ) is low[7] in our case.

Figure 3 : Evolution of $C(L)$ curves for Domar weight residual and equal-weight benchmark



Note : The plots present the adjustment quality of the regressions (6), for a set of L ($L = 5, 10, 15, \dots, 500$) following the approach of (Blanco-Arroyo et al. 2018b). We compare two types of granular residuals: the Equal-weighted residual (benchmark) where the adjustment quality is $C_L^E = \overline{R_E^2(K,L)}$ and the Domar-weighted residual (baseline) with the adjustment quality $C_L^D = \overline{R_D^2(K,L)}$

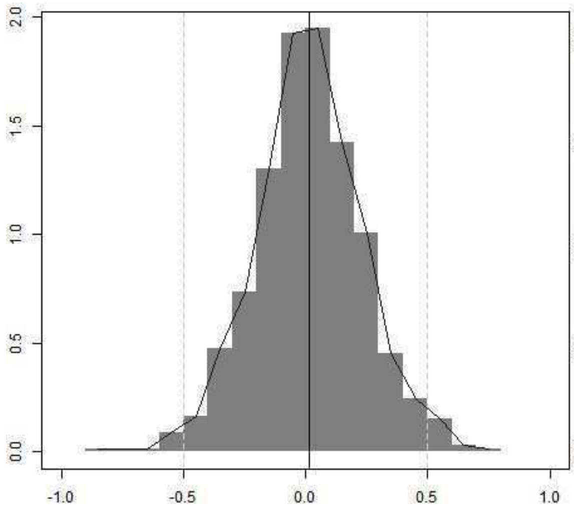
The regressions above are supportive of the granular hypothesis, but these results can suffer from reverse causality. The first problem holds if an aggregate shock drives the aggregate manufacturing sector, and then firm productivity. To assess that the firm-level shock drives

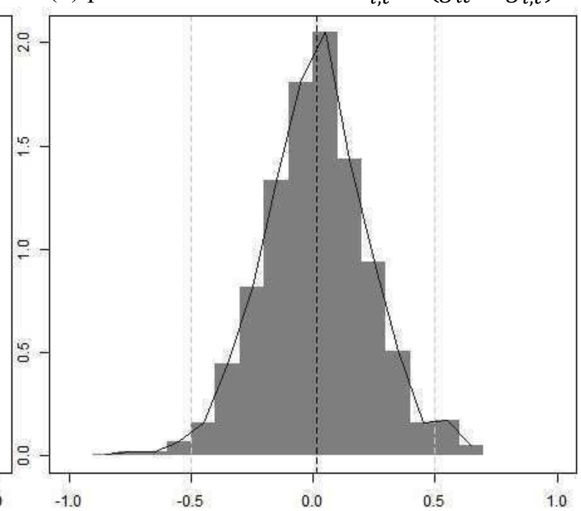
[7] Following, the approximate calibration of Gabaix 2011($\sigma_Y = \mu * h * \sigma$), we calculate h=22% (in line with typical country), σ =50% the volatility of top K firms and $\sigma_Y = 2.4$. The productivity factor is then equal to 0.23, which regressions exhibit similar values.

aggregate fluctuation rather than the reverse, we check the pairwise correlation between idiosyncratic shocks. For model (6.a), the mean of these pairwise correlations is 0.016. Furthermore, they are distributed around zero: 50% of these pairwise correlations lie between -0.12 and 0.16, and more than 80% are ranging from -0.27 to 0.28 (figure 3.a). The diagnostic is still the same for the industrial demeaned model (6.b) as it appears in figure 3.b. These results suggest strong evidence against the reverse causality.

Figure 4 : Idiosyncratic shock pairwise correlation

(a) pairwise correlation of $\varepsilon_{i,t} = g_{i,t} - \bar{g}_t$ (b) pairwise correlation of $\varepsilon_{i,t}^I = (g_{it} - \bar{g}_{i,t}^I)$





Note : the plots display the histograms of the pairwise correlations of firms levels shocks. Panel (a) presents the results of the demeaned shock while panel (b) gives the results of the industrial demeaned shocks.

While the pairwise correlation insights are only suggestive, we propose, as a final robustness check, to control idiosyncratic firm shocks for macroeconomic shocks. To that, we use the main traditional predictors in the Moroccan economy. Given that it's a high open economy, we control for the external shock. We also control for the monetary policy shock and the fiscal policy shock. The relevance of the granular residual after this checking would suggest that firm-level shocks are idiosyncratic as they are independent of macroeconomic shocks and their contribution (granularity) is significant.

To do this, we estimate the following model :

$$g_t^Y = \beta_0 + \beta_1 \Gamma_t + \gamma X'_t + \eta_t \qquad (7)$$

Where X is the vector of the chosen exogenous variables (expressed in the same form as the endogenous variable g_t^Y). We have chosen the interbank interest rate as a proxy for the monetary policy shock (R_t) as a proxy for the monetary policy shock, the public expenditure

(G_t) as a representative of the fiscal policy shock and Euro GDP[8] (Y_t^e) as an indicator of the external shock. To better interpret the relevance of Γ_t We estimate several variants of this model. Note that we restrict ourselves to the instantaneous residual because the lagged residual is systematically insignificant, and controlled by the general average (as supposed to reflect the previous control for macroeconomic shocks).

Table 2 gives the results of the econometric estimations of regression 7. It shows that the relevance of the granular residual remains systematically valid, despite the addition of the other macroeconomic shocks, and significant predictor of manufacturing value-added. Note that only the external shock is significant among the additional exogenous variables adopted. Compared to this significant external shock, the granular residual brings an incremental $\bar{R}^2$ of 15%, from 32% to 47% (comparison between models 11 and 12 of Table 2). This ultimately allows for a better understanding of the fluctuations in Moroccan manufacture but also its forecasting.

Table 2: The granularity of the Moroccan Manufacturing sector with control

Endogenous variable : g_t^Y								
Models	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
β_0	0.0164*	0.0191**	0.0173***	0.0191***	0.0325***	0.0270***	0.0228***	0.0200***
	(0.0092)	(0.0070)	(0.0056)	(0.0051)	(0.0069)	(0.0046)	(0.0080)	(0.0065)
Y_t^e	0.7745**	0.2861	0.7575***	0.5054**				
	(0.2671)	(0.2435)	(0.2386)	(0.2405)				
R_t	0.0074	0.0067			0.0054	0.0070		
	(0.0068)	(0.0051)			(0.0077)	(0.0049)		
G_t	0.0804	0.0674					0.0873	0.0879
	(0.0834)	(0.0628)					(0.0912)	(0.0740)
Γ_t		0.2208***		0.1410**		0.2650***		0.1961***
		(0.0623)		(0.0593)		(0.0521)		(0.0569)
R^2	0.4017	0.6845	0.3243	0.4731	0.0281	0.6290	0.0418	0.3992
$\bar{R}^2$	0.2820	0.5943	0.2921	0.4204	-0.0291	0.5827	-0.0038	0.3391
# of obs.	19	19	23	23	19	19	23	23

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Note: this table shows the estimation results of the model (7) with R_t the interbank interest rate, G_t the public expenditure, Y_t^e the Euro's GDP, and Γ_t the granular residual. The endogenous variable is the annual growth of industrial value-added (g_t^Y).

Source: WDI, Moroccan Ministry of Finance, IMF.

[8] The Euro zone is the main trading partner of Morocco. Its share in Moroccan foreign trade reached 67.4% in 2017.

4. Conclusion

The findings of our investigation lend support to the notion that the granularity hypothesis is a viable means of addressing fluctuations within the manufacturing sector in a low middle-income country. Specifically, our research reveals that idiosyncratic shocks experienced at the micro-level by the leading firms, or grains, account for over one-third of the aggregate volatility witnessed in the Moroccan manufacturing sector. However, it is worth noting that there exists a disparity between our findings and those documented in developed countries, with respect to the productivity factor, or the aggregate productivity response to plant-level productivity. Our research shows that this factor is significantly smaller in Morocco, which may be attributed to the relatively weaker integration observed in low middle-income countries, as noted in the literature (reference). Furthermore, our results demonstrate that the granularity effect is robust, as even the top 45 manufacturing firms in Morocco are sufficient to yield our findings. Finally, we have taken care to ensure the idiosyncratic nature of firm-level shocks through controlling for the reflection problem and aggregate macroeconomic shocks.
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