What is behind aggregate productivity growth in Ireland? A granular approach

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Research Paper

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Summary

This paper is aimed to empirically test for Ireland the "granular hypothesis" (Gabaix 2011), which posits that firm-level productivity shocks can explain a sizable portion of aggregate productivity fluctuations.

The Irish case is particularly relevant as Ireland has been experiencing increasing economic concentration in recent years, to the point that micro shocks to a few selected firms in 2015 led to significant level shifts in aggregate variables like GDP (+34 per cent) and, particularly, labour productivity (+23 per cent) and total factor productivity (-12 per cent).

Combining macro data from the CSO and the OECD with micro data from the Annual Business Survey of Economic Impact (ABSEI), the granular hypothesis is tested in Ireland for the period 2000-2016.

Research findings confirm that productivity shocks to the 5 largest firms (in terms of value added) in Ireland account for a large fraction (about one-third) of aggregate productivity growth. These empirical results shed light on the origins of Irish productivity fluctuations, the consequences of economic concentration on resilience and the importance of diversification policies aimed at broadening Ireland's enterprise base of productive firms.

Keywords: Productivity, Granularity, Aggregate Fluctuations, Micro-Macro Shocks, Ireland.

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I. INTRODUCTION

The mainstream view on business cycle postulates that fluctuations of macroeconomic variables (e.g. GDP, employment, productivity) are mainly caused by aggregate shocks, since uncorrelated sector- or firm-level shocks cancel out if averaged over a large number of sectors or firms.

However, identified economy-wide shocks (inflation, wars, strikes, policy changes) are only able to explain a small fraction of the observed aggregate fluctuations (Cochrane, 1994). Recent studies (Acemoglu et al., 2012) provide the insight that in an economy where a few sectors serve as major input suppliers, specific shocks to these sectors can propagate (through input-output linkages) to generate aggregate fluctuations.

At a more microeconomic level, Gabaix (2011) made a major contribution by positing theoretically (and proving empirically for the US) the so-called "granular hypothesis", which postulates that since modern economies are dominated by large firms, idiosyncratic (productivity) shocks[1] to these firms may not cancel out on average. In fact, firm-level outcomes can lead to sizeable aggregate shocks that affect macroeconomic variables like GDP, employment and aggregate productivity.

This insight can have important implications for policies aimed at increasing economic resilience and competitiveness in countries with a large economic concentration, which are the ones where the granular effects are expected to be stronger than they would be in the US.

The granular hypothesis is particularly relevant for small open economies like Ireland, where the cornerstone of its growth model has been to attract highly-productive multinational enterprises (MNEs) over the past decades. The presence of a small cohort of large and productive MNEs within a narrow range of sectors has led to a large concentration of the Irish economy with significant impacts on aggregate performance.

For example, the unprecedented GDP growth of 26 per cent in 2015 (later revised to 34 per cent) was mainly driven by a few MNEs relocating their entire balance sheets to Ireland, containing intellectual property products. Associated with these relocations were significant increases in the contract manufacturing of goods exports attributable to Ireland. The unexpected increase in capital investment also had a knock-on effect on aggregate labour productivity, which went up by 23 per cent, and total factor productivity, which went down by 12 per cent, with respect to 2014 (CSO 2018).

Furthermore, the granular impact of a few enterprises shows up in a number of other areas. Revenue Commissioner's analysis reveals that 10 largest firms in Ireland account for almost 40 percent of corporation tax receipts in 2017. Ireland's export base in terms of the range of products and destinations, and the profile of exporters, also appears relatively concentrated.

[1] The productivity shocks can come from a variety of product, process, organisation or marketing innovations like a decision of the firm's research department, of the firm's chief executive officer, of how to process shipments, inventories, which new line of products to try or relocations of assets across balance sheets.

CSO data shows that the top five exporters accounted for almost one-third of all goods exports in 2016.

From a more granular perspective, the OECD has recently published firm-level research (Papa et al 2018) showing that the top 10 per cent of firms in Ireland, by gross output, account for 87 per cent of value added and 73 per cent of employment in manufacturing. In services, the contributions to value added and employment from the largest firms is higher than manufacturing, with a share of approximately 96 and 87 per cent, respectively.

Another measure of market concentration is the Herfindahl-Hirschman Index (HHI)[2], where Ireland scored in 2011 the highest value in both manufacturing and services compared to other advanced economies like France, Germany, Italy, Denmark, Netherlands and Japan. Overall, value added, employment and the HHI are more concentrated in Ireland than in the other OECD countries for which comparable estimates exist.

The same research shows that the top performing firms in manufacturing (defined as those located between the 90th and 100th percentiles of the labour productivity distribution) account for 70 per cent (on average) of aggregate productivity over the period 2006-2014, and just under 80 percent in 2014. In services, the impact of the most productive firms on productivity is lower than in manufacturing but is nonetheless substantial. The top 10 per cent most productive firms in services account for 46 per cent (on average) of aggregate productivity over the period, trending upwards after the crisis from 37 per cent in 2008, to 56 per cent in 2014.

This productivity research based on a micro-aggregated approach, although one of the first ones in Ireland, was carried out on a sample of surveyed firms operating in selected sectors (mainly manufacturing and non-financial services) over the 2006-2014 period. As such, it was not intended to be representative of all sectors in the Irish economy. Nor was it aimed to link firm-level shocks to aggregate fluctuations in Ireland.

Therefore, the main objective of this research paper is to test Gabaix's granular hypothesis on the entire Irish economy and thus examine to what extent (unexpected) productivity shocks to the largest firms have an impact on macroeconomic variables like GDP and, more importantly, aggregate (multifactor) productivity.

The empirical work of Gabaix (2011) originally showed that productivity shocks to the largest 100 firms in the United States appear to explain a large fraction (about one-third) of variations in GDP per head and aggregate productivity growth between 1952 and 2008. Similar studies for other countries (Lin & Perez 2014) found that shocks to large firms roughly explain about one third of output fluctuations in Germany, but they are not significant in the UK and Canada.

Since GDP measures in Ireland have been the subject of much discussion in recent years, particularly after the 34 per cent level shift in 2015, the focus of this research paper will be

[2] The HHI is calculated as the sum of the squared market shares (by gross output) of all firms in a given industry.

about the granular effects on aggregate multifactor productivity, which is a central macroeconomic variable for a number of reasons.

Productivity growth is a key factor of national competitiveness as it enables firms to compete successfully in international markets by facilitating output to be produced in a more efficient and effective manner. This means that, ultimately, productivity is the engine of economic growth over the medium to longer term, the main driver of improvements in living standards, a key determinant of the sustainable wage level, and a key factor determining our ability to finance public services.

Two measures of productivity are commonly used, namely (i) labour productivity, which is measured as output (e.g. GDP or GVA) per person engaged or output per hour worked; and (ii) total factor productivity (TFP), which measures the efficiency which both labour and capital are used together in the production process. Total factor productivity distinguishes from labour productivity as it controls for the capital intensity of firms or capital deepening in the economy (i.e. capital per worker).

Since the contributions from labour and capital are subject to demographic constraints, and diminishing returns, respectively, long-term economic growth is driven fundamentally by (multi factor) productivity, which can also be seen as an approximate measure of innovation or technical change.

II. DATA AND METHODS

Two sets of macroeconomic and firm-level data are combined in this paper to empirically test the granular hypothesis on Ireland.

Macroeconomic data series like real GDP and GDP per capita are taken from the OECD while the GDP deflator, which is the inflation index used in the analysis, is taken from the World Bank. More importantly, the aggregate measure of total factor productivity used in this work comes from 'TFP Solow Residual' data series recently published by the CSO.

Firm-level data are obtained from the Annual Business Survey of Economic Impact (ABSEI) as provided by the Department of Business, Enterprise and Innovation. This is a survey of the client companies of Enterprise Ireland, IDA Ireland and Údarás na Gaeltachta. The population comprises approximately 4,200 agency client firms, in the manufacturing and internationally-traded services sectors, employing ten or more employees in Ireland. The ABSEI has been collected each year since 2000 up until 2016. Enterprises surveyed over the period 2000-2014 represent about 75 per cent of total Irish exports, declining to 65 per cent in 2015-2016, which makes the ABSEI representative of large exporting companies.

Due to the large level shift in GDP (and TFP) in 2015, the econometric analysis of this paper is carried out for the period 2000-2014. However, as shown later, the same results hold for the extended period 2000-2016.

Although ABSEI is an unbalanced panel data, where some observations are missing or replaced from year to year, most of the surveyed firms remain clients of Enterprise Ireland,

IDA Ireland and Údarás na Gaeltachta typically for a number of years, which facilitate the comparative analysis.

Following Gabaix's approach, the data cleaning procedure involves the removal of all missing observations for value added, sales (where appropriate for each) and the number of employees hired by the firm as well as all values at or below zero for these variables. This cleaning procedure results in just under 2,000 firms in earlier years increasing to just over 2,600 in later years, which is unlikely to have affected the largest firms.

Due to the presence of large outlying observations, which may result from extraordinary events such as mergers or relocation/consolidations of balance sheets, extreme demeaned[3] growth rates are capped if larger than 20 per cent in absolute terms. This procedure was implemented to follow Gabaix's original approach and thus allow for comparability. However, restricting productivity shocks to a maximum of 20 per cent affected around 40 per cent of the top 100 firms in Ireland over the entire period. For robustness check purposes, higher thresholds of demeaned growth rates (e.g. at 50 per cent) were implemented and the results reported below.

Industries comprise the Manufacturing and Information, Communication and Other Internationally Traded Services sectors, according to the NACE Rev 2 codes at two-digit level of disaggregation.

Unlike Gabaix's original approach, which excluded financial firms because the nature of their sales is not in line with the meaning of gross output [used] in the paper, this work includes the financial sector because the measure of gross output used is not sales but value added as explained below. Besides, the financial services sector -as per the ABSEI- includes both financial and insurance companies as well as a large group of financial technology services (or 'fintech') and other IT-related enterprises[4].

Another amendment to Gabaix's original model is the use of value added, instead of sales, as a measure of gross output and to calculate firms' labor productivity[5] (when divided by their number of employees). This is a sensible choice in a small open economy like Ireland where the share of (imported) intermediate inputs into exports is increasing over time thus decoupling sales from gross value added, GDP and TFP trends. As of 2016, Ireland was one of 5 countries in the world where the value of exports (and imports) exceeds that of GDP.

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3 Data normalization through de-meaning implies that average/mean growth rates by year or by year and industry are subtracted from each individual firm's growth rates.

4 The exclusion of the financial services sector from the analysis would result in a substantial reduction of the sample size for Ireland, where the contribution of this sector is sizeable. In fact, when we remove the financial services sector from the sample the granular residual turns out to have a non-significant impact on aggregate productivity. The most plausible explanation is that the productivity distribution of firms in the sector firms is skewed towards the right or fat-tailed, which means a few firm have very high productivity growth rates. This is nonetheless a condition for the granular effect to be significant.

5 Lin & Perez (2014) show that TFP and labour productivity measures at firm level are highly correlated and yield similar results on granularity.

Value added in the ABSEI is defined as sales minus the total cost of materials and services, which are then deflated to create real value-added figures[6]. The granular residual, which represents a weighted-average of productivity shock to large firms, is then calculated as follows:

$$\Gamma_{LP,K}(t) = \sum_{i \in K} \frac{S_i(t-1)}{Y(t-1)} \left(g_{LP,i}(t) - \bar{g}_{LP}(t) \right)$$

where $\Gamma_{LP,K}(t)$ is the granular residual based on productivity growth, *LP* stands for labour productivity, *K* indicates the number of top firms (ranked by value added) over which the granular measure (either 100 or 5) is computed. The ratio S_i / Y measures the share of firm *i*'s value-added in GDP in the previous period *(t-1)*. Finally, the idiosyncratic shock to firm *i* is measured as $g_{LP,i}(t) - \bar{g}_{LP}(t)$, that is the growth rate of labour productivity of firm *i*, normalised by the mean growth rate of the largest Q firms (=100) by year and industry (two-digit level).

The impact of the granular residual on aggregate fluctuations is then measured by regressing the aggregate (total factor) productivity growth $g_{TFP(t)}$ on the current $\Gamma_{LP,K(t)}$ and past (productivity) granular residuals $\Gamma_{LP,K(t-1)}$ & $\Gamma_{LP,K(t-2)}$, and assessing the total explained variance (or explanatory power) via the R^2 statistics:

$$g_{TFP(t)} = \beta_0 + \beta_1 \Gamma_{LP}(t) + \beta_2 \Gamma_{LP}(t-1) + \beta_3 \Gamma_{LP}(t-2) + \epsilon_1(t)$$

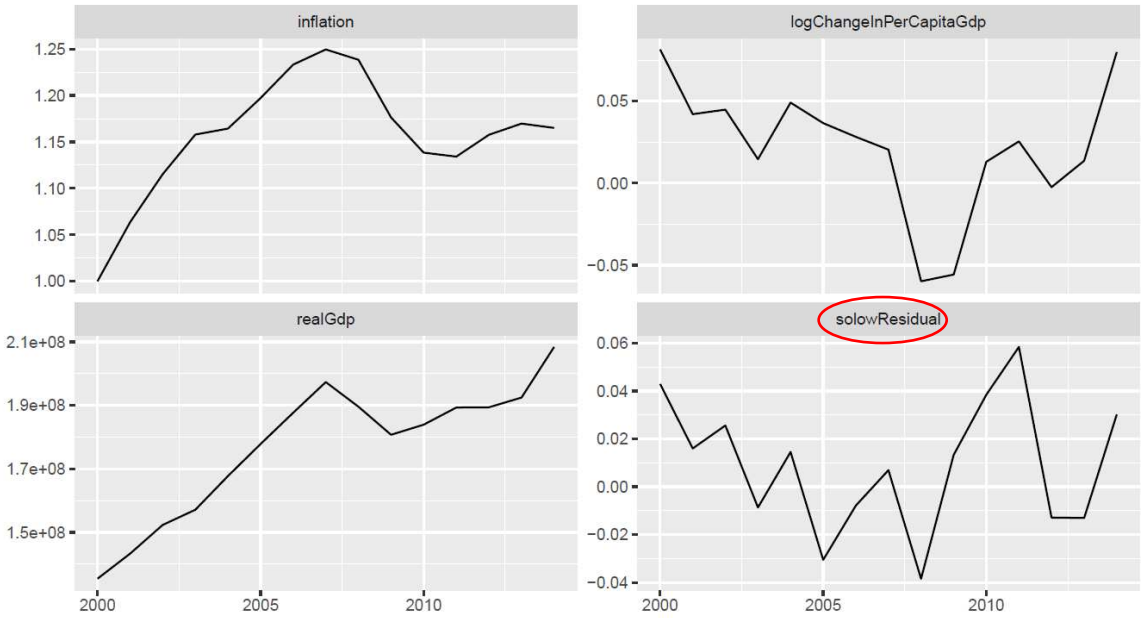
III. EMPIRICAL RESULTS

The first descriptive statistics depicted in Figure 1 show the change over time (2000-2014) in key macroeconomic variables used in this work such as inflation (used to deflate nominal values) and real GDP (used to calculate firm-level share/contribution to the granular residual). More importantly, Figure 1 shows the change over time in aggregate total factor productivity (TFP), which is measured as Solow Residual[7]. Ireland's aggregate productivity growth has been falling from 2000 up until the 2008 crisis when it bounced back to positive growth rate before levelling off around near zero growth rates (on average). Besides, productivity volatility has increased substantially after the 2008 crisis.

[6] Ideally, we would have used industry production price indexes, but we follow Gabaix's straightforward approach and use GDP deflators instead.

[7] The so-called Solow Residual is the most common measure used to calculate total factor productivity. It is, basically, the residual output growth left after calculating the contributions from labour and capital.

Figure 1. Key macroeconomic data (inflation, real GDP, GDP p/capita and TFP), 2000-2014

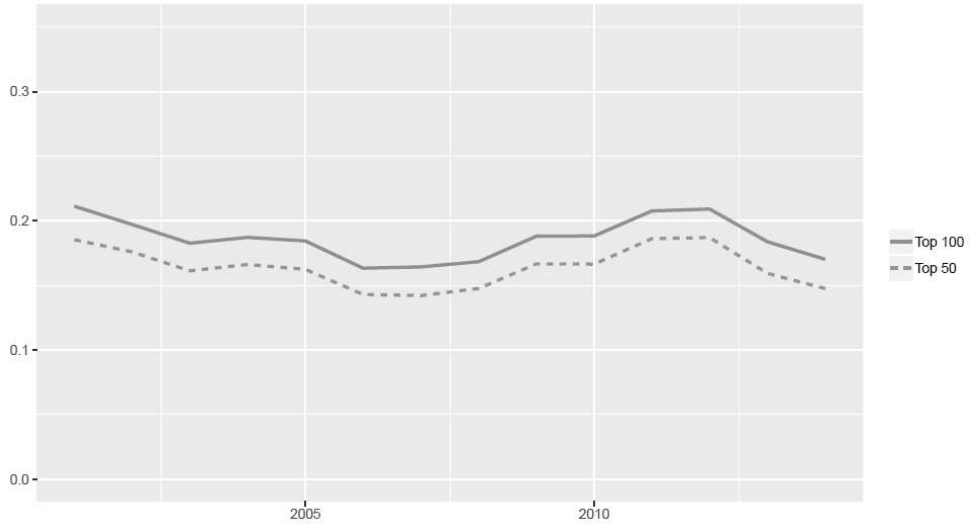


Note: Inflation is expressed as an index 2000=1; Real GDP is expressed in euros; and both change in GDP per capita and the Solow Residual are expressed in rates of change.

Sources: CSO for TFP (Solow Residual), OECD for GDP and World Bank for Inflation

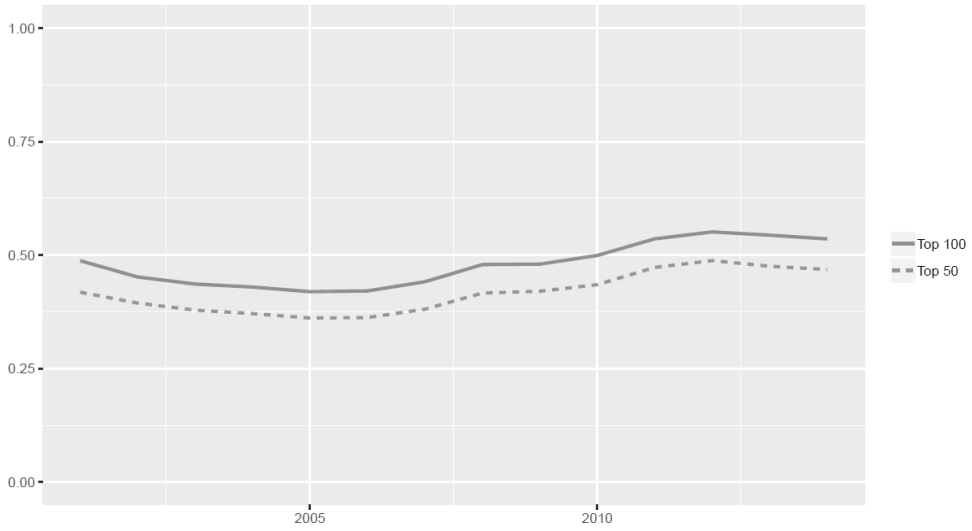
Figures 2a show that the value added of the 100 largest firms from the ABSEI account for 20 per cent of GDP (on average) over the period 2000-2014. In terms of sales, the proportion of GDP of the 100 largest firms account for nearly 50 per cent (on average) of GDP over the same period, as shown in Figure 2b. These results are very similar for the 50 largest firms in the ABSEI, which highlight the substantial contribution that a few large firms make to the Irish economy as a whole.

Figure 2a. Value-added of top 100 & 50 firms as proportion of GDP, 2000-2014



Source: Author's calculations based on ABSEI

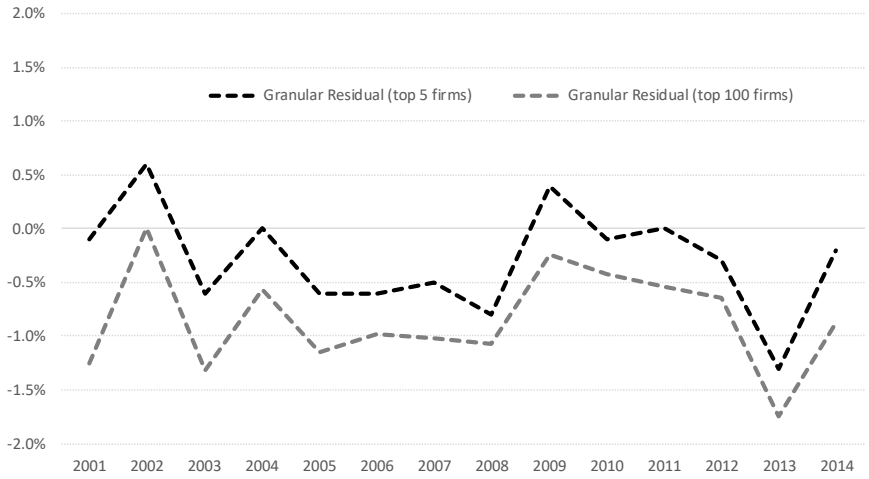
Figure 2b. Sales of top 100 & 50 firms as proportion of GDP, 2000-2014



Source: Author's calculations based on ABSEI

Figure 3 shows the declining trend of (mostly negative) productivity shocks to the 100 and 5 largest firms between 2001 and 2008, which coincides with the declining trend of aggregate TFP (Solow Residual) depicted in Figure 1.

Figure 3. Granular residual fluctuations (micro productivity shocks), 2000-2014



Note: Granular residual expressed as percentage rate of annual change.

Sources: Author's calculations based on ABSEI

The positive productivity shock observed in 2009, resulting from a rebound to the 2008 crisis, gradually came to an end culminating with marked negative shocks in 2012 and,

particularly 2013, most likely as a result of the 'patent cliff'[8] that impacted Pharma-Chemicals products. Since the sector accounted for a substantial share of value added (11 per cent in 2012), this micro shock was also reflected in the sharp fall of aggregate productivity over the same period (Figure 1).

Table 1 presents the econometric regression of Ireland's aggregate productivity (TFP Solow Residual) on the granular residual of the top 100 (columns 1 & 2) and top 5 largest firms (columns 3 & 4) in terms of value added in the previous period.

Despite the minor amendments made to Gabaix's original model, the results for Ireland add further support to the granular hypothesis and show similar coefficients to the ones originally tested for the United States.

Table 1. Explanatory power of the (productivity) granular residual

	Dependent variable: **TFP Solow Residual**			
	Top 100 firms		*Top 5 firms*	
	(1)	(2)	(3)	(4)
GranularResidualUsingYearAndIndustryDemeaning_Contemporaneous	3.649**	3.685*	3.626**	4.123**
	(1.527)	(1.859)	(1.303)	(1.626)
GranularResidualUsingYearAndIndustryDemeaning_OnePeriodLag	0.401	0.817	-0.122	0.044
	(1.479)	(1.643)	(1.300)	(1.378)
GranularResidualUsingYearAndIndustryDemeaning_TwoPeriodsLag		1.928		1.431
		(1.941)		(1.703)
Constant	0.039*	0.058*	0.016*	0.022*
	(0.021)	(0.028)	(0.008)	(0.011)
Observations	13	12	13	12
R^2	0.369	0.423	0.439	0.486
Adjusted R^2	0.242	0.206	0.327	0.293
Residual Std. Error	0.024 (df = 10)	0.025 (df = 8)	0.023 (df = 10)	0.024 (df = 8)
F Statistic	2.919 (df = 2; 10)	1.952 (df = 3; 8)	3.911* (df = 2; 10)	2.520 (df = 3; 8)

*Note 1: Significance levels at: *p<0.10 **p<0.05 ***p<0.01*
Note 2: Standard errors in parentheses
Note 3: Period covered 2000-2014; results still robust for 2000-2016.

In particular, the first row of Table 1 shows that contemporary productivity shocks (granular residual) to the 100 largest firms, and even to the 5 largest firms, do have a significant and sizable impact on Ireland's aggregate productivity (TFP Solow Residual). Unlike studies for other countries, productivity shocks in previous periods do not seem to have a lasting effect on aggregate productivity growth. This might be related to the negligible spillover effects to other firms (mostly Irish-owned) from productivity shocks originating in the largest firms (mostly foreign-owned) as Di Ubaldo et al (2018) have found for Ireland.

[8] The term patent cliff refers to the phenomenon of patent expiration dates and an abrupt drop in sales (and value added) that follows for a group of products capturing a high percentage of a market.

More importantly, the explanatory power of this granular model, as measured by the Adjusted R^2 statistics, is reasonably high for the top 100 firms (at 24.2 per cent) and even higher for the top 5 firms (at 32.7 per cent). This indicates that idiosyncratic movements of very few firms (top 5) are enough to explain aggregate fluctuations and the granular effects dissipate as the number of firms increase (top 100). Ultimately, if only aggregate shock were important, then the explanatory power of the model or Adjusted R^2 of the regression in Table 1 would be zero.

The 5 largest firms that make a substantial contribution to aggregate productivity operate in the following industries: Pharmaceutical & chemical; Computer programming; Computer, electronics & optical products and, more recently, Food, drink & tobacco.

Another important finding is the fact that the granular effect of productivity shock for Ireland (Γ_t = 3.6) seems to be larger than that originally found for the United States (Γ_t = 3.3). As Gabaix (2011) pointed out "granular effects are likely to be even stronger outside the United States, as the United States is more diversified than most other countries". Indeed, the Herfindahl-Hirschmann index of economic concentration for Ireland is amongst the largest of any OECD countries (Papa et al 2018).

Due to the large level shift in GDP (and hence TFP) in 2015, the regression analysis of this paper has covered the period 2000-2014. However, robustness checks for the extended period 2000-2016, which included a time dummy in 2015, showed the same results for the contemporary granular coefficient.

One of the major limitations of this study is the reduced sample size of 15 years, which comes down to 13 observations when growth rates and lagged variables are calculated. With the exception of the original study for the US, which included 55 year-observations, reduced sample size is not only an Irish problem. Previous studies that calculated granular effects for Germany and the UK were limited to sample sizes including approximately 20 year-observations (Lin & Perez 2014). However, the fact that Ireland's contemporary granular coefficient or diffusion effect[9] (Γ_t = 3.6) as well as the explanatory power of the model (R^2 = 33 per cent, for the top 5 firms) are similar to those found for the United States (Γ_t = 3.3 and R^2 = 33 per cent) provides reassurance that the regression results are pointing in the right direction.

For comparability purposes, the year-industry demeaned productivity growth rates were capped at 20 per cent (in absolute terms) following Gabaix's original specification to restrict the influence of outliers. In the case of Ireland, however, this approach affected around 40

[9] This coefficient can be interpreted as the contemporary diffusion or propagation effect to other firms and the wider economy (via input-output linkages, for example) as a result of micro productivity shocks to large firms. However, other spillovers effects (via labour mobility, for example) could be more easily understood when the granular residual is lagged one or two periods, which in the Irish case turned out to be non-significant.

per cent of the top 100 firms over the entire period. When this conservative procedure is relaxed to allow for firm-level productivity shocks of up to 50 per cent of demeaned growth rates, the regression results are slightly different. The contemporary granular residual Γ_t or diffusion effect decreased (from 3.6 to 2), while the adjusted R^2 or explanatory power of the model increased (from 33 per cent to 43 per cent) which, nevertheless, further confirms the granular hypothesis and highlights the importance of outlying observations (i.e. firms with unusual growth rates) in the Irish economy.

IV. CONCLUSIONS, POLICY IMPLICATIONS AND NEXT STEPS

These empirical findings confirm the granular hypothesis that productivity shocks to very few large firms seem to account for a large fraction (about one-third) of aggregate productivity fluctuations. The impacts seem to be larger for Ireland than for the US due to the higher economic concentration and less diversification.

To understand the origin of aggregate productivity growth better, policy makers should not focus exclusively on aggregate and exogenous shocks like inflation, trade or interest rate, but on concrete micro shocks to large firms, for example in the ICT and Pharma-Chemical sectors. These results also suggest that policy makers might wish to incorporate the granular residual in their macroeconomic forecasting to improve the predictions of aggregate productivity fluctuations.

More importantly, these findings draw attention to the consequences of economic concentration in Ireland. Figure 1 showed that volatility of aggregate productivity (TFP Solow Residual) is getting increasingly higher and it is likely to go further up if economic concentration continues to increase over time. Besides, the fact that lagged productivity shocks to large firms do not seem to have a lasting impact on aggregate productivity growth raises concerns about limited spillover effects from the largest firms to the wider economy.

As indicated in the National Competitiveness Council's (NCC) Productivity Statement 2018, broadening and diversifying Ireland's enterprise and export base is critical to ensuring the Irish economy is resilient and adaptable to both large firm- and industry-specific shock, particularly in view of the global tax and trade environment.

Along these lines, the Department of Business, Enterprise and Innovation's Future Jobs Ireland focuses on actions to maximize the contribution of large multinational enterprises to the Irish economy and increase the productivity of SMEs to bridge productivity gaps and thus ensure a more sustained aggregate productivity growth.

Access to longer time series with administrative data, including non-agency-supported firms, might help to further validate the significant results found for TFP fluctuations and possibly test again the non-significant results found for GDP fluctuations.

Moreover, access to richer datasets with more variables would allow us to test empirically the impact of other types of idiosyncratic shocks on aggregate productivity. For instance, Dosi

et al (2018) provide empirical evidence of a so-called demand granularity, based on investment growth shocks instead. This approach would be of relevance for Ireland where investment in intangibles assets has been growing at a very rapid pace over the past decades (Corrado *et al* 2012).

**

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