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The drivers of revenue productivity: a new decomposition analysis with firm-level data

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This paper presents research conducted within the Competitiveness Research Network (CompNet). The network is composed of economists from the European System of Central Banks (ESCB) - i.e. the 29 national central banks of the European Union (EU) and the European Central Bank – a number of international organisations (World Bank, OECD, EU Commission) universities and think-tanks, as well as a number of non-European Central Banks (Argentina and Peru) and organisations (US International Trade Commission). The objective of CompNet is to develop a more consistent analytical framework for assessing competitiveness, one which allows for a better correspondence between determinants and outcomes.

The research is carried out in three workstreams:

1) Aggregate Measures of Competitiveness;

2) Firm Level;

3) Global Value Chains

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Abstract

This paper aims to derive a methodology to decompose aggregate revenue TFP changes over time into four different components – namely physical TFP, mark-ups, quality and production scale. The new methodology is applied to a panel of EU countries and manufacturing industries over the period 2006-2012. In summary, patterns of measured revenue productivity have been broadly similar across EU countries, most notably when we group them into stressed (Italy, Spain and Slovenia) and non-stressed countries (Belgium, Finland, France and Germany). In particular, measured revenue productivity drops for both groups by about 6 percent during the recent crisis. More specifically, for both stressed and non-stressed countries the drop in revenue productivity was accompanied by a substantial dip in the proxy we use for TFP in quantity terms, as well as by a strong reduction in mark-ups. Demand also suffered a conspicuous decline. Our results suggest that non-stressed countries seem to enjoy a stronger recovery in terms of fundamentals like quantity TFP, demand and mark-ups than stressed countries. Yet, their overall performance in terms of revenue TFP recovery does not necessarily align with the above analysis which is due to some possible deterioration in the resource reallocation, signalled in our framework from the lower covariance between the two components we split revenue TFP.

Keywords: Decomposition, Production function estimation, Demand, Productivity, Markups

JEL: E32, O47, D24

Executive Summary

Defining productivity is relatively simple: it is the measure of how much output can be obtained out of given inputs. Turning this concept in empirical terms is much less straightforward, however, as pointed out by an extensive literature. There are three main issues researchers have to face (Syverson, 2011), namely i) how to proxy the output, ii) how to define and measure the inputs and iii) how to estimate productivity, particularly total factor productivity (TFP), which is the most popular and comprehensive indicator. In this paper we focus on the output issue and provide a decomposition of *aggregate* TFP changes over time.

To fix the ideas, let's look at a balance sheet of a firm and search for the item "output". At best, and if the underlying business is extremely simple - i.e. the firm produces a single manufacturing product - we may find some indication of the number of units manufactured and their price, as well some info on the cost of inputs used in production. In the vast majority of the cases, however, we will not have - or be able to derive directly - a quantity measure of production. Rather, we will only have an indication of the total revenue generated by selling a firm's production. This is because, typically, firms' activity will be a complex combination of products and services sold at a variety of unit prices, using a multiplicity of inputs.

In such common, real life situation, when we measure productivity using the available total revenues we invariably incur in a number of measurement errors we should very much be aware of, in order to avoid gross misinterpretation of the results. One of the most prominent issue is the extent in which the "quality" of the output sold is reflected in its price. When this is not the case, the recorded (revenue) productivity is not only a pure result of production efficiency, but rather a complex object involving a number of other factors, i.e. (i) tastes on the demand side, and (ii) of product market conditions – most notably degree of prevailing market competition - on the supply side. In addition, the overall size of the underlying production by individual producers will have an impact on the respective measured productivity due to economy of scale effects, which will potentially raise productivity of the larger producers.

In this paper, we give an account on the importance of these different effects by breaking down revenue total factor productivity (TFPR) into several components and providing a decomposition of *aggregate* TFPR changes for a a panel of EU countries and manufacturing industries over the period 2006-2012. To do so we draw on the framework developed by Forlani et al. (2016) and use data from CompNet – a firm-level based data set – and PRODCOM – a production database with a fine product-level disaggregation and containing information on both physical quantities and sales.

Forlani et al. (2016) propose a firm-level model in which productivity, as well as demand and mark-ups are heterogeneous across firms. The framework is consistent with both monopolistic competition as well as with some forms of oligopolistic market structures. In the model the mark-up is defined as the ratio of the price to the marginal production costs and is related to the elasticity of demand. In turn, demand heterogeneity is modelled in a way that is complementary to heterogeneity in mark-ups and that can be interpreted as a measure of quality of a firm's products.

The novelty of the model is that it takes into consideration several dimensions of heterogeneity, formerly treated in a restrictive way by previous literature.

Building upon the above model, in this paper we derive a methodology to decompose *aggregate* revenue TFP changes over time into four different components – namely physical TFP, mark-ups, quality and production scale - and apply it to a panel of EU countries.

The empirical estimation using micro- and product-level data yields a number of notable results, which have potentially high relevance on the "narrative" of the recent crisis.

- Over the period 2002-2012 patterns of measured revenue productivity have been broadly similar across EU countries, most notably when we group them into stressed (Italy, Spain and Slovenia) and non-stressed countries (Belgium, Finland, France and Germany). In particular, measured revenue productivity drops for both groups by about 6 percent during the recent crisis.[1]

- The relative "modest" fall in revenue productivity hides however a number of much more substantial changes in underlying fundamentals.

- More specifically, for both stressed and non-stressed countries the drop in revenue productivity was accompanied by a substantial dip in the proxy we use for TFP in quantity terms, as well as by a strong reduction in mark-ups. Such changes in mark-ups have been particularly important to help firms mitigate the consequences of the financial crisis on their revenue productivity. Demand also suffered a conspicuous decline.

- Such changes have been less marked for non-stressed countries that have been able to mitigate the negative impact of the financial crisis by leveraging more the inputs use rather than the mark-up margin.

- In terms of where the countries in our sample stand as of 2012 the overall picture that emerges is one in which non-stressed countries seem to enjoy a stronger recovery in terms of fundamentals like quantity TFP, demand and mark-ups than stressed countries. Yet, their overall performance in terms of revenue TFP recovery does not necessarily align with the above analysis. The reason for this has to do with some possible deterioration in the resource reallocation, signalled in our framework from the lower covariance between the two components we split revenue TFP. Such deterioration in resource use is also confirmed by alternative indicators computed within the CompNet dataset.

- Further investigations at the sector level show that all industries have reacted in a similar way with only marginal cross-sector deviations in the extent to which demand has plunged during the crisis.

[1] The term "Stressed economies" refers to the euro area countries which either are/were participating in a financial assistance programme (e.g. Spain) or, as in the case of Italy, Portugal and Slovenia, have macroeconomic imbalances which the European Commission has labelled as "excessive". These countries also experienced significant market turbulence from 2010 until at least summer 2012.

Overall, our analysis confirms there is a substantial loss of precious information when measuring and assessing productivity developments based solely on the most common practice, i.e. using revenue based measures alone. Using detailed firm-level and product-level information we are able to disentangle more in depth the roots of such developments. The worsening of resource reallocation which has been found for non-stressed countries calls for further investigation.

1. Introduction

Generally speaking, defining productivity is relatively simple: it is the measure of how much output can be obtained out of given inputs. Turning this concept in empirical terms is much less straightforward, however, as pointed by an extensive literature (see Syverson, 2011 for a review). There are three main issues a researcher has to face, i.e. on the output, the inputs and the formal estimation of TFP.

First, the output measure is typically available in terms of revenue rather than in terms of physical quantities, which are either not observable, or are blurred by the fact that the firm produces a multiplicity of goods. This in principle would not be an issue if prices perfectly reflected the underlying quality of the goods. Yet, even in such a case, an additional layer of complication arises when considering firms facing different local market conditions. Clearly, the resulting revenues will depend on both their respective market powers and the efficiency of their production. In such situation revenue productivity must be corrected by some measure of relative market power like, for example, mark-ups. The second issue regards the inputs. For labour, the choice is between using number of employees or hours worked, with or without quality adjustment. For capital the usual caveat is that there are not satisfactorily measures of physical capital, including the absence of an agreement on how to take into account the role of intangibles and in general the quality of the inputs. The third issue is the actual measurement of the TFP and in particular how to get a satisfactory weighting system of the different inputs.

In this paper we concentrate on the first set of issues and study the underlying components of revenue productivity. In line with existing literature we underline four main factors we are interested into, i.e. quantity total factor productivity (TFP), quality, mark-ups and production scale and point to them as main drivers of the observed high heterogeneity across firms. Unlike previous literature, however, our approach allows a broader and contemporaneous treatment of the various drivers. Indeed, previous literature - either for the choice of the underlying market structure, or because of data limitations - has normally opted for either (i) just looking at a subset of such components, or (ii) imposing strong limitations to the behaviour of some of them. For example, Klette and Griliches (1996) after recovering quantity TFP, allow some demand shocks in the background, but impose homogenous mark-ups across firms. In a similar vein, De Loecker (2011) introduces demand shocks in a revenue-based production function model while relying on CES preferences; his framework is very parsimonious, as it only requires revenue data, but it imposes a common mark-up across varieties. By contrast, Foster et al. (2008) use data on both the quantity and the value of a firm's production in order to disentangle productivity shocks from demand shocks; they focus however on homogeneous goods and also have to assume that productivity shocks are uncorrelated to demand shocks. De Loecker and Warzynski (2012) and Dobbelaere and Mairesse (2013) estimate both quantity TFP and firm-level mark-ups, but do not explicitly consider demand shocks, which are left in the background.

More specifically, drawing from Forlani et al. (2016), we decompose revenue productivity into four components, i.e. 1) physical TFP, 2) mark-ups, 3) quality, and 4) production scale. Our framework allows firms to differ in terms of both their physical productivity and the quality of the goods they produce. At the same time we are able to recover mark-ups and use them to properly account for differences in market power. Last but not least production scale also matters in our analysis because we allow for, among others, increasing or decreasing returns to scale in the production function.

Empirically, while Forlani et al. (2016) focus on Belgian firms, we analyse revenue productivity patterns of several EU countries and further provide a decomposition formula for *aggregate* revenue productivity changes. We consider in particular two sets of determinants, related to 1) quantity TFP, demand and mark-ups (COMP1) and 2) production scale and mark-ups (COMP2). Importantly, we analyse the extent the above two set of components covaries, claiming that a decreasing covariance would represent a proxy for a worsening in the resource reallocation. Overall, our findings allow getting fresh insights on how the determinants of the revenue productivity evolved overtime, particularly around the time of the financial crisis and the extent in which resource reallocation could be a contributing factor of such developments.

The rest of the paper is organized as follows. Section 2 contains the conceptual framework for decomposing revenue productivity. Section 3 provides information about data sources. Section 4 contains the results of our empirical analysis. Section 5 concludes.

2. Conceptual framework

Underlying Model

We consider an industry model where firms, indexed by i, produce quantity Q_{it} and generate revenue R_{it} subject to a Cobb-Douglas production function:

$$Q_{it} = L_{it}^{\alpha_{jL}} K_{it}^{\alpha_{jK}} \Omega_{it} \tag{1}$$

where t denotes time, L_{it} is labour used and K_{it} is the corresponding capital, Ω_{it} is quantity TFP and α^{jL} and α^{jK} are time-invariant production function coefficients that we assume to be common across firms belonging to industry j. Equation (1) can be written in log-linear form as:

$$q_{it} = \alpha_{jL} l_{it} + \alpha_{jK} k_{it} + \omega_{it} \tag{2}$$

where, as usual, small case letters indicate the log of a variable. Our analysis allows production technology parameters to be different across countries. To save space, however, in what follows we omit country indices. Data on quantity is typically not available to researchers and so revenue is used instead of quantity to measure productivity. More specifically, by replacing log quantity q_{it} with log revenue $r_{it}= q_{it}+ p_{it}$ in (2) we have:

$$r_{it} = \alpha_{jL} l_{it} + \alpha_{jK} k_{it} + \omega_{it}^{r} \quad (3)$$

where ω_{it}^{r} is revenue productivity is in general different from quantity productivity ω_{it} due to heterogeneity in prices p_{it}.

Drawing from Forlani et al. (2016), we decompose revenue productivity ω_{it}^{r} as a function of actual physical productivity, quality, mark-ups and production scale. The decomposition derives from a model where heterogeneity in prices is fuelled by differences in terms of quality (denoted by Λ_{it} for the level and by λ_{it} for log, respectively) and mark-ups (denoted by μ_{it}) across firms as well as in quantity TFP. The mark-up $\mu_{it}>1$ in Forlani et al. (2016) is simply the ratio of the price to the marginal production costs and is related to the elasticity of demand. Our framework is consistent with both monopolistic competition as well as with many oligopolistic market structures like, for example, the ones considered in Atkeson and Burstein (2008). To be more specific, from the profit maximization condition (marginal revenue equal marginal cost) one derives:

$$\frac{\partial r_{it}}{\partial q_{it}} = \frac{1}{\mu_{it}} \quad (4)$$

i.e, the elasticity of revenue with respect to quantity equals one over the markup. In terms of quality Forlani et al. (2016) model it as demand shifters affecting firms in a way that is complementary to heterogeneity in mark-ups. More precisely, if products 1 and 2 are characterized by quality Λ_1 and Λ_2 (with $\Lambda_2 = 2\Lambda_1$), the consumer would be indifferent between consuming c units of product 2 or 2c units of product 1. Under this definition of quality one can show that:

$$\frac{\partial r_{it}}{\partial \lambda_{it}} = \frac{\partial r_{it}}{\partial q_{it}} = \frac{1}{\mu_{it}} \quad (5)$$

i.e. the elasticity of revenue with respect to quality coincides with the elasticity with respect to quantity and equals one over the markup. This means that, within this setting, everything works as if firms were selling quantity $Q_{it}^{*} = Q_{it}\Lambda_{it}$ while charging a price $P_{it}^{*} = P_{it}/\Lambda_{it}$ and generating revenue $R_{it}^{*} = P_{it}^{*}Q_{it}^{*} = P_{it}\,Q_{it} = R_{it}$.

Turning to the revenue TFP decomposition formula Forlani et al. (2016) show that:

$$\omega_{it}^{r} = \frac{1}{\mu_{it}}(\omega_{it} + \lambda_{it}) + \frac{(1-\mu_{it})}{\mu_{it}}\bar{q}_{it}, \quad (6)$$

where $\bar{q}_{it} = \alpha_{jL} l_{it} + \alpha_{jK} k_{it}$ is an index of production scale (or input use) utilizing production function coefficients as weights for labour and capital. Equation (6) shows how revenue productivity is, everything else equal, positively related to both quantity productivity, ω_{it}, and quality, λ_{it}.[2] As for mark-ups, μ_{it}, it can be shown that $\frac{\partial \omega_{it}^{r}}{\partial \mu_{it}} < 0$, i.e. as firms expand sales along the more elastic portions of the demand (so lowering mark-ups) they increase, everything else equal, revenue productivity. At the same time, however, an expansion of production scale $\bar{q}_{it}$ lowers revenue productivity at a rate $\frac{(1-\mu_{it})}{\mu_{it}}$.

Implementing the Model

Ideally we would like to estimate the above model using firm-level inputs, quantity and revenue to back out the corresponding values of quantity TFP, quality and mark-ups across firms as in Forlani et al. (2016). We would also like to further consider materials expenditure as an additional input as in Forlani et al. (2016). However, firm-level quantity data is not available to us. What we have instead is product-level quantity and revenue data (PRODCOM database). At the same time the firm-level revenue productivity data which is available to us (COMPNET database) has been computed using only labour and capital as inputs and value added as output (materials expenditure data is present in the raw COMPNET dataset but has been used simply as a proxy variable in the revenue productivity estimation). It is not possible for us at this stage to use the raw COMPNET data and run revenue TFP estimation using revenue as output and three inputs; future research will likely expand in this direction. Last but not least only average (across firms) capital, labour expenditure and value added at the industry level is available from COMPNET. In light on these restrictions we take a leap of faith and conduct the analysis at the product-level instead of the firm-level. Therefore, in what follows i actually refers to an 8-digit PRODCOM product, j denotes a 2-digit NACE rev 2 sector and by revenue we actually mean value added.

Turning to the revenue productivity decomposition in Section 5 we will show how observed changes over time in revenue productivity across products and countries can be decomposed into the four elements described above. However, in order to make equation (6) operational we need two further assumptions. First, we further assume that the number of firms N producing product i varies little over time ($N_{it}=N_i$); an assumption that is compatible with the short time horizon of our analysis as well as with the raw data. This allows us to neglect the extensive margin and focus on the total revenue coming from sales of product i at time t and the total production of product i at time t. Second, we also assume that capital and labour are used in the same proportions across all products $i \in j$.

Using COMPNET 2-digits NACE rev 2 data on the production function coefficients (α^{jL} and α^{jK}), as well as firm average use of labour (l_{jt}) and capital (k_{jt}), we can readily compute ω_{it}, up to a product-specific constant, by combining them with the log quantity q_{it} from PRODCOM. Please note that:

[2] In models featuring lumpy investments and, like Caliendo and Rossi-Hansberg (2012), an increase in quantity productivity and/or demand can actually decrease revenue productivity. This happens because, after the lumpy investment has been realized in order to increase the quantity produced, the marginal cost goes down by more than the increase in productivity and/or demand. Caliendo et al. (2015) build on Forlani et al. (2016) to explicitly analyze this behavior.

$$\omega_{it} = q_{it} - \bar{q}_{it} = q_{it} - (\alpha_{jL} l_{it} + \alpha_{jK} k_{it}) = q_{it} - (\alpha_{jL} l_{jt} + \alpha_{jK} k_{jt}). \quad (7)$$

In particular, the last equality comes from the assumption that capital and labour are used in roughly the same proportions across all products i ∈ j. The COMPNET dataset directly provides information on average revenue productivity at the industry level (ω^r_{jt}) that we assign to all i ∈ j ($\omega^r_{it} = \omega^r_{jt}$). The COMPNET dataset can also be used to recover mark-ups. Indeed Forlani et al. (2016) show that equilibrium mark-ups obey the rule:

$$\mu_{it} = \frac{\alpha^{jL}}{s_{Lit}} \quad (8)$$

where s_{Lit} is the share of labour costs in total value added. The production function labour coefficient α^{jL} is directly provided by the COMPNET database while, building on the Cobb-Douglas and common technology assumptions, we impose $s_{Lit}=s_{Ljt}$ for all i ∈ j and compute s_{Ljt} as the ratio between labour costs and valued added at the industry-level.

With information on μ_{it}, ω_{it}, ω^r_{it} and $\bar{q}_{it}$ in our hands we can finally invert equation (6) to back out the relevant value of the quality parameter λ_{it}. In this respect note that λ_{it} is a kind of residual variable that allows (6) to hold as an equality; for that reason is in general expected to be less precise than other variables.

Decomposition

In principle we could analyse the time evolution of revenue TFP and its different components for every country-product pair in the data. Yet to economize on space and focus on the broad features of the data we aggregate at the country level. More specifically we define the following aggregate revenue TFP change at the country level:

$$\Delta\Omega^r_t = \sum_i \frac{\Omega^r_{it}}{\Omega^r_{it-1}} w_{it-1} \quad (9)$$

where we use product-year-specific revenue data from PRODCOM to construct weights $w_{it-1} = R_{it-1}/R_{t-1}$ and $R_t = \sum_i R_{it}$. In equation (9) the ratio of revenue productivity today to revenue productivity yesterday ($\Omega_{it}/ \Omega_{it-1}$) is aggregated across products using weights w_{it}. Note that, with this definition, any product-specific time-invariant element (like the unit of measurement of the product and/or what left by our use of 2-digits capital and employment data instead of l_{it} and k_{it} and/or the number of producing firms N_i) disappears.

Equation (9) allows us to look at aggregate revenue productivity changes over time as a function of changes in quantity TFP, quality, mark-ups and production scale. Yet, analysing changes of the individual four components is not straightforward since one needs to keep track of the covariance (across products) of the four different components for things to actually sum up. To solve the issue we therefore consider a more parsimonious decomposition of revenue TFP to get a first impression of the data. From equation (6) we have that the ratio $\Omega_{it}^{r}/\Omega_{it-1}^{r}$ can be rewritten as the product of two components:[3]

$$\Omega_{it}^{r}/\Omega_{it-1}^{r} = Comp1 * Comp2$$

where

$$Comp1 = \frac{(\Omega_{it}\Lambda_{it})^{1/\mu_{it}}}{(\Omega_{it-1}\Lambda_{it-1})^{1/\mu_{it-1}}}$$

$$Comp2 = \frac{(\bar{Q}_{it})^{1-\mu_{it}/\mu_{it}}}{(\bar{Q}_{it-1})^{1-\mu_{it-1}/\mu_{it-1}}}.$$

Comp1 summarizes the changes in the combined TFP/quality margin between t-1 and t with each in turn being raised to a power corresponding to that year's mark-up. *Comp2* instead measures changes in the size of production, i.e. inputs used, between t-1 and t with each in turn being raised to a power related to that year's mark-up. This provides our baseline decomposition of $\Delta\Omega_{t}^{r}$ into three elements: *Comp1*, *Comp2* and their covariance.

In sum with the above framework we can:

1. Analyze the time evolution of revenue TFP.

2. Analyze the time evolution of quantity TFP, quality, mark-ups and inputs use. These four elements, along with their covariances, contribute to generate aggregate revenue TFP changes.

3. The specific effects that impact on revenue TFP can be summarized by *Comp1*, *Comp2* and the covariance between the two components. The covariance between the two can be interpreted as a proxy for the degree of resource misallocation. More specifically, in a well-functioning market, products experiencing an increase in quantity TFP and/or quality can be expected to gain market shares and see their production and input use responding rapidly and accordingly. In that case, the covariance would be positive. In the presence of misallocation and/or sluggish adjustment we should instead observe a lower contemporaneous covariance between changes in fundamentals and input use.[4]

[3] Remember that $\omega_{it}^{r} = \log(\Omega_{it}^{r})$.

[4] In terms of the overall understanding it is also important to note that both *Comp1* and *Comp2* have a negative first derivative with respect to mark-ups at time t (μ_{it}). This means that, everything else equal, a drop in mark-ups (like the one we will see later on characterizes the core Financial crisis year 2009) would increase both *Comp1* and *Comp2* and so overall aggregate revenue TFP. More broadly, it is important to note that both *Comp1* and *Comp2* are sensitive to changes in mark-ups because μ_{it} and μ_{it-1} enter (9) as powers.

3. Data sources

CompNet

Data for country-sector-year specific indicators are obtained from the database provided by the Competitiveness Research Network (CompNet). The database comprises a large set of firm-level-based indicators that are related to competitiveness for 17 EU countries, around 60 sectors and a time span of 15 years.

In order to preserve confidentiality of firm-level information and to improve cross-country comparability, CompNet has adopted the so-called "distributed micro-data approach" as developed by Bartelsman et al. (2004). In this approach a common protocol is used to extract relevant information from existing firm-level datasets available within each National Central Bank (NCB) or National Statistical Institute (NSI) and aggregate it such that the confidentiality of firm data is preserved. The common methodology harmonizes industry coverage, variable definitions, estimation methodologies and sampling procedures. The result is a wide range of indicators, based on micro-level data, which could be used systematically for analysis of competitiveness related issues.

Relevant for our purposes, the CompNet includes average employment and capital use by country, sector and year. Moreover, CompNet also includes data on revenue-based TFP, estimated by applying the formula below:

$$TFPR_{it} = \frac{RVA_{it}}{rK^{\widehat{\beta}_1} \cdot L^{\widehat{\omega}}},$$

where RVA_{it} is the real value added as presented in the balance sheet of the firm, rK is the real capital and L is the number of employees. Indices i and t describe the sector and the year, respectively. The coefficients $\hat{\beta}_1$ and $\widehat{\omega}$are obtained from estimating the following production function via GMM following the approach by Wooldridge (2009):

$$\mathrm{rva}_{it} = \beta_0 + \beta_1 \mathrm{rk}_{it} + \beta_2 \mathrm{rk}_{i(t-1)} + \beta_3 \mathrm{m}_{i(t-1)} + \beta_4 \mathrm{rk}^2_{i(t-1)} + \beta_5 \mathrm{m}^2_{i(t-1)} + \beta_6 \mathrm{rk}^3_{i(t-1)} + \beta_7 \mathrm{m}^3_{i(t-1)} + \beta_8 \mathrm{rk}_{i(t-1)} \mathrm{m}_{i(t-1)} + \beta_9 \mathrm{rk}_{i(t-1)} \mathrm{m}^2_{i(t-1)} + \beta_{10} \mathrm{rk}^2_{i(t-1)} \mathrm{m}_{i(t-1)} + \gamma \mathrm{Year}_t + \omega \mathrm{l}_{i(t-1)},$$

where lower case letter correspond to the logarithmic value of the variable and m is the material input used.

PRODCOM

The PRODCOM database provided by EUROSTAT contains statistics on production of manufactured goods for European Union countries (+ Norway and Iceland). In particular, PRODCOM data includes the physical volume and the value of production sold during the survey period.

The data is obtained by the National Statistical Institutes (NSIs) who conduct a survey of enterprises. The survey is based on the PRODCOM List, consisting of about 3900 products. The 8-digit codes used in the List are based on the 6-digit CPA headings and hence the 4-digit NACE rev 1.1. From 2008 onwards the PRODCOM code is linked to CPA 2008 and NACE Rev. 2. The link to NACE enables the NSIs to use the Business Register to identify the enterprises likely to be manufacturing the product. The PRODCOM List is revised every year. PRODCOM covers sections B and C of NACE Rev.2 and C, D and E of NACE Rev 1.1.

The purpose of the statistics is to report, for each product in the PRODCOM List, how much has been produced in the reporting country during the reference period. This means that PRODCOM statistics relate to products (not to activities) and are therefore not strictly comparable with activity-based statistics such as Structural Business Statistics. The NACE codes on which PRODCOM codes are based merely serve to identify the enterprises that should be surveyed in order to determine the amount of production of the product.

The NSI in each reporting country carries out a survey of industrial production in that country, collates the results and transmits them to EUROSTAT. EUROSTAT calculates EU totals and publishes the national and EU data together with the related external trade data. The value is expressed in national currency but where necessary converted to Euro by EUROSTAT. The volume is expressed in a unit specified for each product.

4. Results

The combined COMPNET-PRODCOM data allows us to analyze revenue productivity for the manufacturing sector of the following countries over the period 2006-2012[5]: Austria, Belgium, Croatia, Estonia, Finland, France, Germany, Hungary, Italy, Lithuania, Poland, Portugal, Romania, Slovakia, Slovenia and Spain (see Figure 1 for a subsample).

[5] CompNet data is available between 2002 and 2012. The two databases have been matched using 2 digit NACE Rev. 2 industry codes for each country and year. PRODCOM data compatible with NACE Rev. 2 are available from 2005 onwards. This means the first year we can compute changes is 2006.

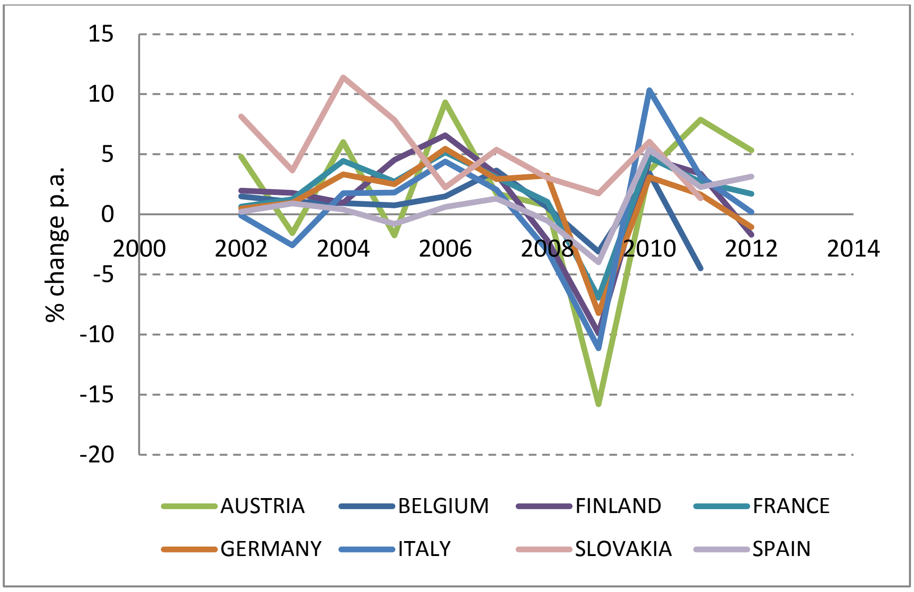


Figure 1: % yearly changes in manufacturing revenue TFP

Figure 1 delivers a visual description of % yearly changes in TFPR for some of the countries included in our sample. Before the financial crisis TFPR growth has been in the ballpark of 0 to 5 per cent for most countries. Yet in 2009 TFPR suffered everywhere with all countries but the fast growing Slovakia having negative growth rates and countries like Austria and Italy actually experiencing a plunge of more than 10%. The pattern is very similar and highly synchronized across countries so confirming previous findings about the financial crisis coming from other indicators like international trade and GDP.

Figure 2 groups countries into stressed countries and non-stressed countries. The former group includes Italy, Spain and Slovenia while the latter group comprises Belgium, Finland, France and Germany. Quite surprisingly, the two sets of countries have been almost equally affected in terms of aggregate revenue productivity growth in manufacturing. Before the financial crisis the group of non-stressed countries was benefitting from a somewhat higher TFPR growth. Yet, in 2009, TFPR plunged by about 6% for both groups. The dip is actually slightly more severe for non-stressed countries while the post-financial crisis recovery looks stronger for stressed countries. At the same time, however, the decline in TFPR for stressed countries had already materialised in 2008.

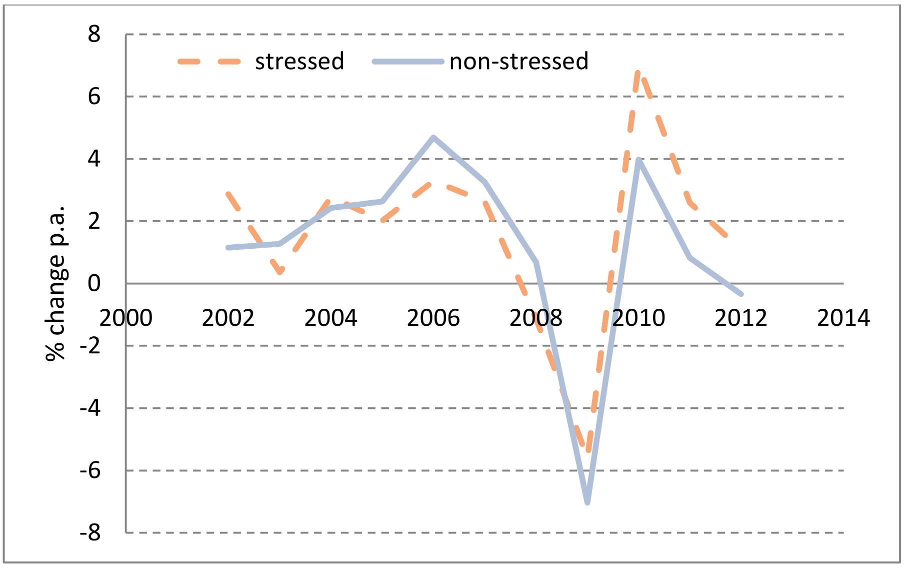


Figure 2: % yearly changes in manufacturing revenue TFP: stressed vs. non-stressed countries

Using the methodology of section 3, Figures 3a and 3b split the change in aggregate revenue productivity into the two components, *Comp1* and *Comp2*, for stressed and non-stressed countries, respectively. Despite some differences in terms of magnitude and timing, that we will also discuss, the overall time pattern of *Comp1* and *Comp2* is quite similar between stressed and non-stressed countries and can be summarized as follows.[6]

Comp1 is a synthetic measure of changes in quantity TFP and demand, as well as mark-ups. It is important to note that the mark-up enters as exponents in the expression. More specifically, a given decline in quantity TFP and/or demand is then amplified/diminished by raising/declining mark-ups. *Comp1* has severely declined around 2008-2009 with a plunge of about 20% and has recovered quite substantially since 2010. The dip has been stronger for stressed countries while the recovery has been more sustained for non-stressed countries. Stressed countries on the other hand started the downturn already in 2008 while for non-stressed countries the worst year has been 2009. Figures 4a to 5b deliver more details about the individual channels affecting *Comp1*. As depicted in Figures 4a and 4b, quantity TFP in both country groups declined substantially more than revenue TFP. Again, the pattern is stronger for stressed countries.

[6] Remember that the change in revenue TFP is decomposed into the product of both components minus the covariance between the two. If either of the two components or the more granular components (inputs use, quant. TFP, markups and demand) is above 1 in the charts below this implies that it has contributed to positive growth in TFPR – and vice versa (disregarding the covariance).

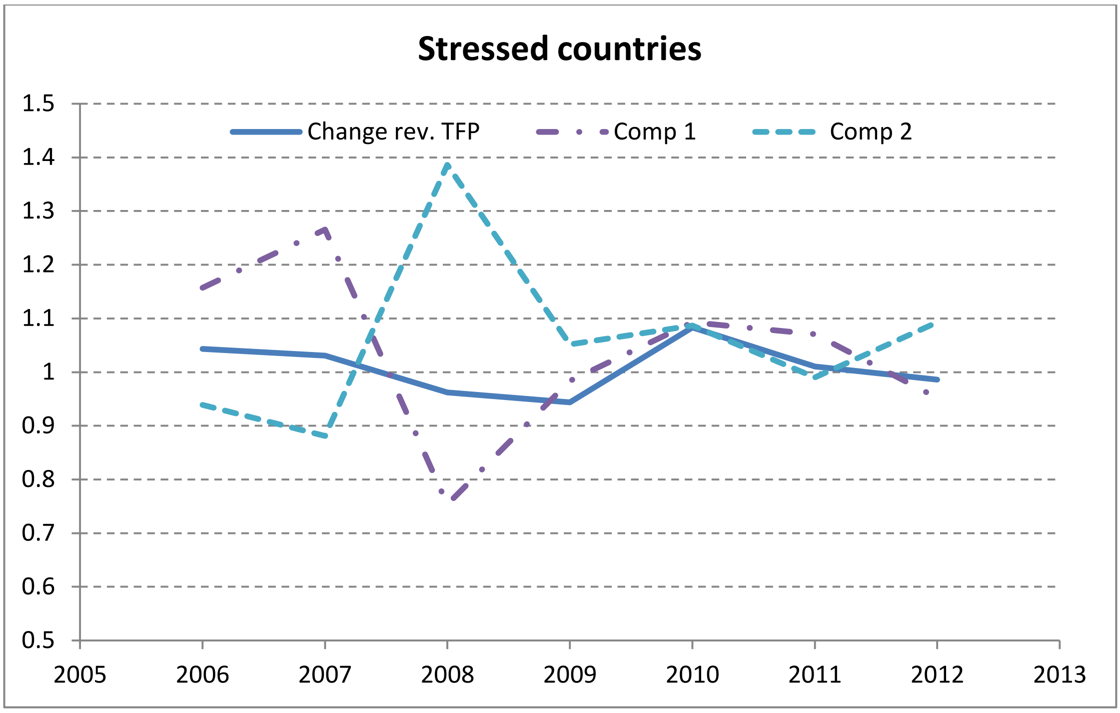


Figure 3a: Changes in TFPR, Comp 1 and Comp2; stressed countries

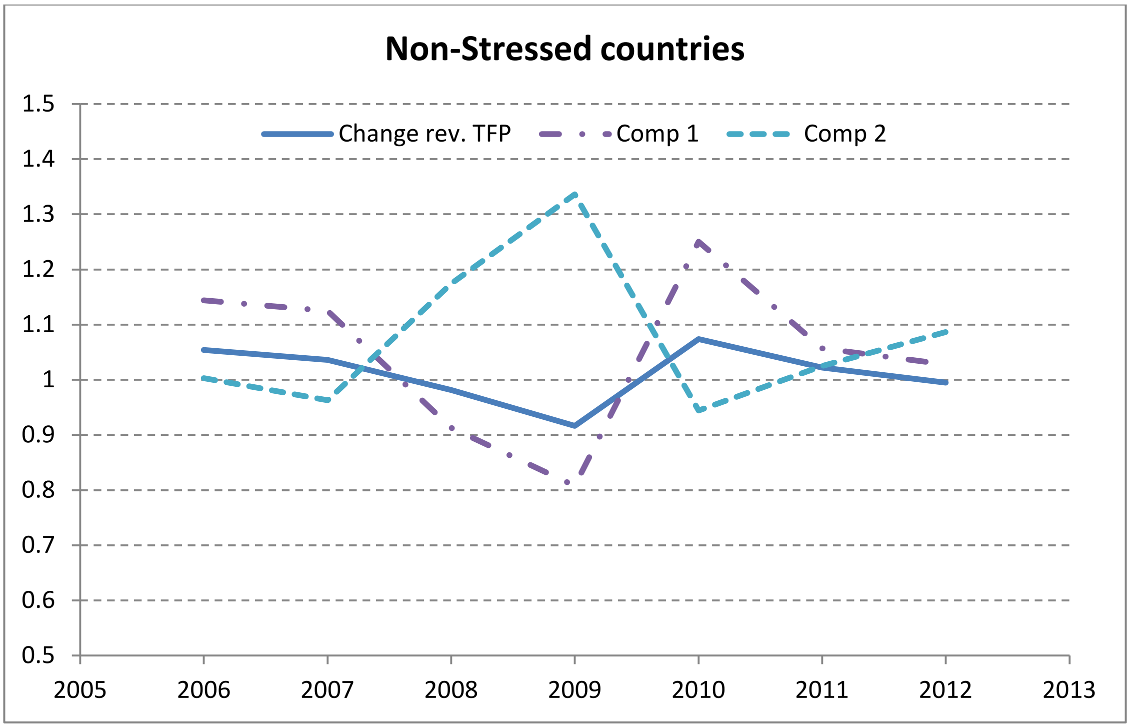


Figure 3b: Changes in TFPR, Comp 1 and Comp2; non-stressed countries

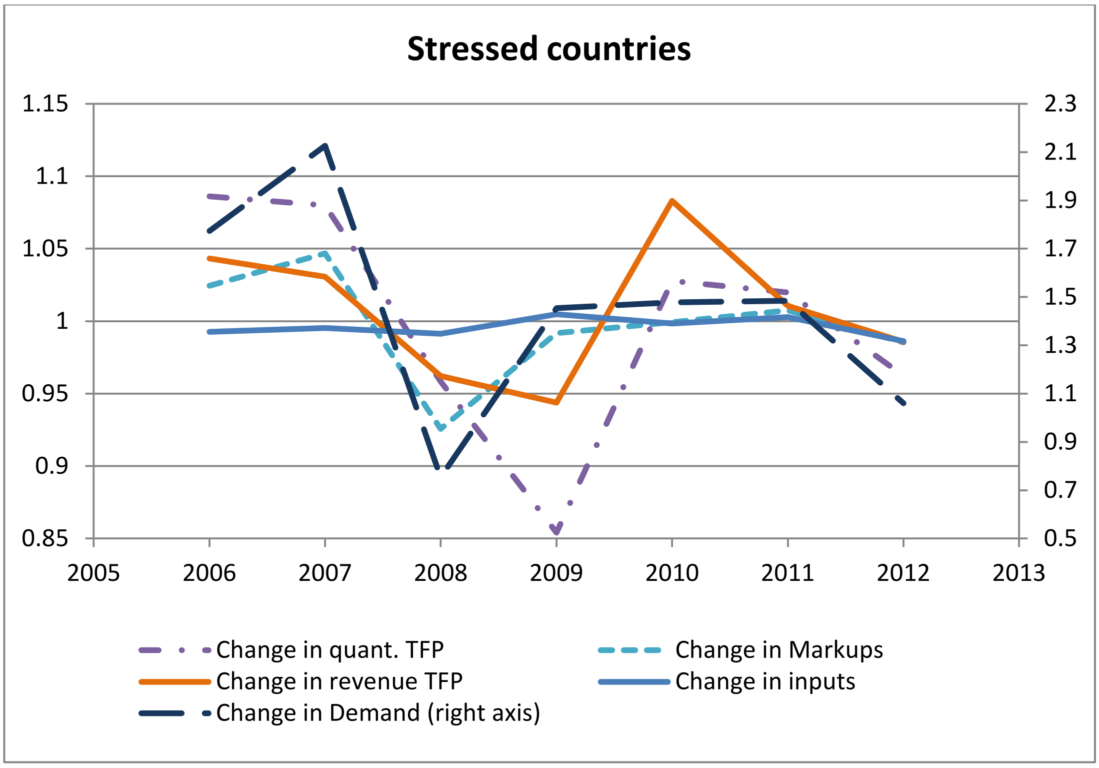


Figure 4a: Changes in inputs use, mark-ups and quantity TFP; stressed countries

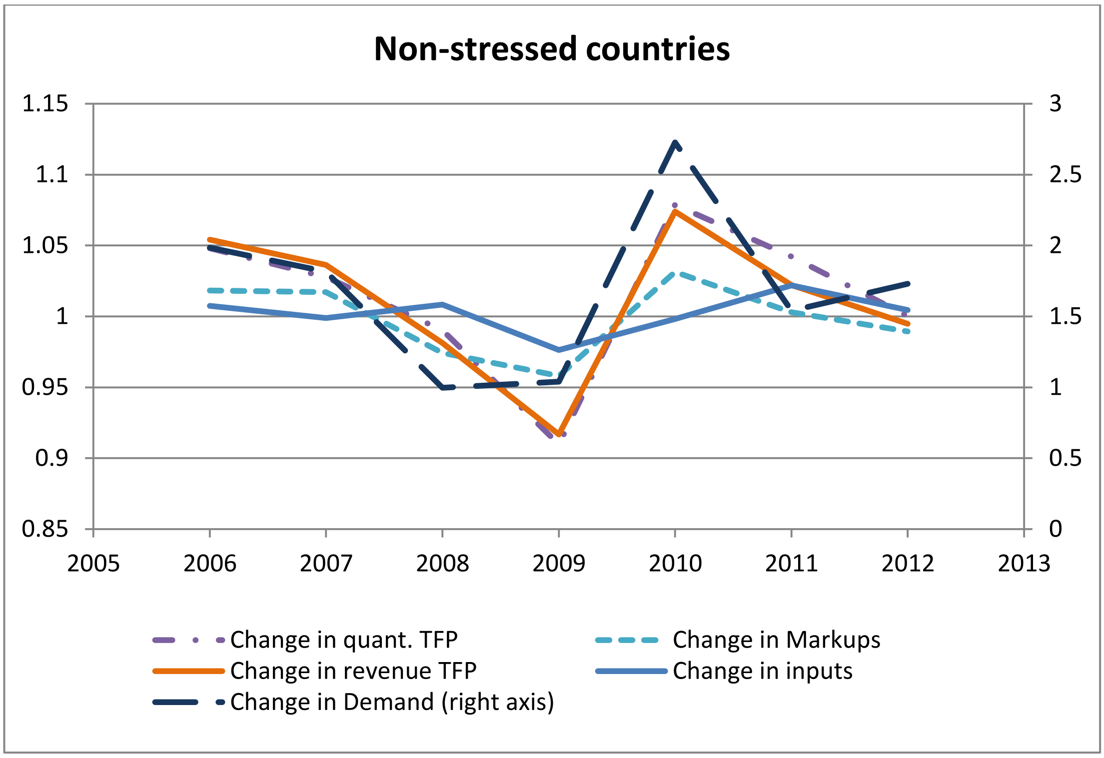


Figure 4b: Changes in inputs use, mark-ups and quantity TFP; non-stressed countries

Furthermore, the time evolution of the demand index *lambda* in Figures 4a and 4b (right axis) also points to a drop in demand that has been much more severe than the overall revenue TFP plunge. Yet, these very strong patterns have been substantially mitigated in both sets of countries by a strong reduction in mark-ups ending up in an overall much lower fall in *Comp1* than what could have been otherwise inferred from the slowdown of quantity TFP and demand. This is presented in Figures 4a and 4b where one can see that mark-ups decreased around 2008-2009 in both stressed and non-stressed countries. The pattern is, again, more pronounced for stressed countries where actually most of the action takes place already in 2008. Implied % mark-ups changes are much lower than quantity TFP and demand implied % changes but, as already discussed, *Comp1* is quite sensitive to mark-ups due to them entering as powers and indeed the observed changes in mark-ups have been sufficient to contain the drop of *Comp1* to about 20-30% in between 2008 and 2009.

In terms of *Comp2* the pattern is reversed. *Comp2* is a synthetic measure of changes in input use as well as mark-ups. As can be seen in Figures 3a and 3b *Comp2* experienced a substantial increase during the financial crisis so counter-balancing most of the negative impact of *Comp1*. This rise in *Comp2* has been determined by both a reduction in inputs use and a decrease in mark-ups. This can be fully appreciated in Figures 4a and 4b, which also underline some differences between stressed and non-stressed countries. More specifically, the former group is characterized by smaller changes in inputs use and larger mark-ups reduction. By contrast, non-stressed countries have been able to mitigate the negative impact of the financial crisis by leveraging more on the inputs use margin rather than the mark-up margin. At the same time the evolution of mark-ups in Figures 4a and 4b suggests that while non-stressed countries are almost back to the pre-financial crisis mark-ups levels by 2012 this is largely not the case for stressed countries. In both cases, however, inputs use has recovered from the financial crisis dip.

To sum up, in spite of fall in revenue productivity of 'only' about 6% in both country groups there have been behind the scene much more substantial changes in underlying fundamental like demand and quantity TFP to which firms have reacted by almost equally substantial counter-actions working via the mark-ups and inputs use margins. Changes in mark-ups have been particularly important to help firms mitigate the consequences of the financial crisis on their revenue productivity. All of this has materialized similarly in both stressed and non-stressed countries even though the magnitude and timing of some specific patterns somewhat differ between the two groups. In terms of where these countries stand as of 2012 the overall picture that emerges from our analysis is one in which non-stressed countries seem to enjoy a stronger recovery in terms of fundamentals like quantity TFP, demand and mark-ups than stressed countries. Yet their overall performance in terms of revenue TFP recovery, as showed by Figure 2, does not necessarily align with the above analysis. The reasons for this has to do with the covariance between *Comp1* and *Comp2* (that contributes to determine $\Delta\Omega_t^r$) worsening markedly for non-stressed countries since the financial crisis; something that can be though as an increase in misallocation. This message is conveyed by Figure 5 where the evolution of such a covariance is reported. In stressed countries the covariance between *Comp1* and *Comp2* has been negatively affected only in 2007 and 2008 and was back to the pre-financial crisis level already in 2009. Yet for the non-stressed country group such a covariance has been lower than it used to be from 2008 onwards so eroding every year the progress made on the fundamentals side.

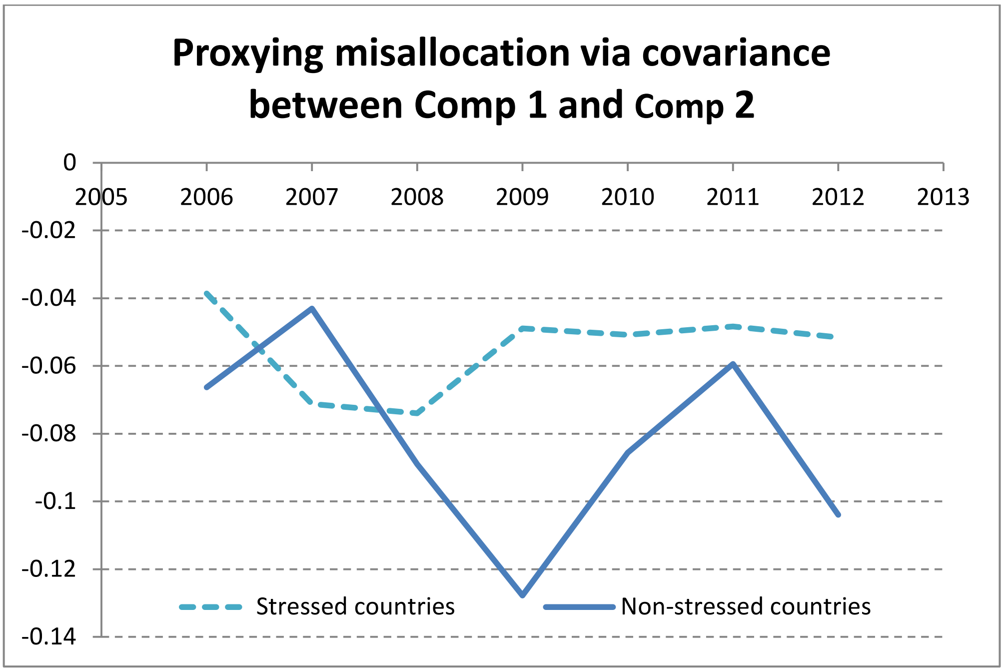


Figure 5: Changes in covariance effect; stressed and non-stressed countries

Interestingly enough, a very similar message is conveyed, as depicted in Figure 6, by a completely different measure of misallocations; namely the OP gap for labour which is included in the COMPNET data following the methodology developed in Olley and Pakes (1996). The OP gap measures the covariance between the relative size of each firm and its productivity, assuming that more productive firms are also the ones that have been growing more.

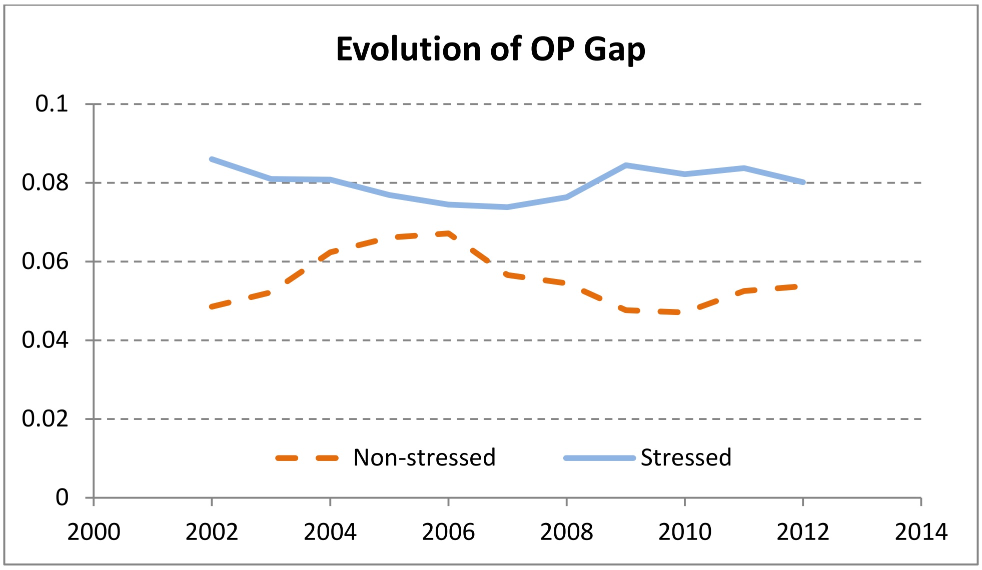


Figure 6: 3-year rolling average of (labour) OP Gap; stressed and non-stressed countries; from CompNet data

TFPR evolution and decomposition at the sector-level

In the following we apply the above TFPR decomposition method at the sector level both for stressed and non-stressed countries. We focus here on two sectors that are among the largest in terms of observations and coverage: sectors 25 (‘Manufacturing of fabricated metal products’, 12,384 observations) and 28 (‘Manufacture of machinery and equipment’, 16,619 observations). This extension of the analysis allows detecting whether all industries have reacted in a similar way to the crisis and to what extend cross-sectoral variation between particularly stressed and non-stressed countries exists.

Figures 7 and 8 depict the TFPR dynamics and the trend of its components for both sectors and the group of stressed and non-stressed economies. Beginning with sector 25, we can see that the evolution of revenue TFP, quantity TFP and firms’ mark-ups are identical to the country-level trends (compare with Figures 4a/b). The changes in demand in this specific sector, however, features a considerably longer lasting decline than observed in other sectors (levels are shown on the secondary axis). Furthermore, the drop in 2008 is more pronounced and did not appear to recover before 2010 suggesting that the decline in TFPR among the stressed countries was mostly demand-driven. On the contrary, for the group of non-stressed countries, product demand has experienced an equally significant decline in 2009 while it behaved relatively stable in 2008. It is also interesting to note that firms in the most stressed countries appear to have been suffering more from declines in quantity TFP than their peers in the group of non-stressed countries. The difference is, however, only marginal.

Turning to sector 28, we can observe similar differences to the country-level decomposition as before: Demand in the group of stressed countries has dropped already in 2008 (even though to a smaller extent than in sector 25) and has recently experienced another drop after only a short period of recovery in 2010. Revenue TFP, quantity TFP as well as firms’ mark-ups feature mostly identical patterns as for the economy-wide decomposition. For the group of non-stressed countries, we can identify pronounced swings in the demand with a prolonged and substantial downward trend in 2008 and 2009 before peaking with higher demand in 2010. The demand changes are followed by more pronounced cycles in the sector-specific TFPR growth than in the other sectors and the overall economy-wide trend.

Taking a more general perspective, the TFPR decomposition at the sectoral level highlights that differences across sectors in terms of TFPR trends exist and appear to be mostly driven by substantial differences in demand changes while the other factors, i.e. quantity TFP and mark-ups of firms, feature only marginal deviations across sectors. The sectors for which this is particularly true are 25 and 28 – as shown above – but also for the sectors 10 (‘Manufacture of food products’, 20,014 observations), 14 (‘Manufacture of wearing appeal’, 8,126 observations) as well as 20 (‘Manufacture of chemicals and chemical products’, 13,747 observations). The other sectors are substantially less covered with fewer than 1,000 observations per year and sector and are therefore less suitable for a sector-specific analysis.

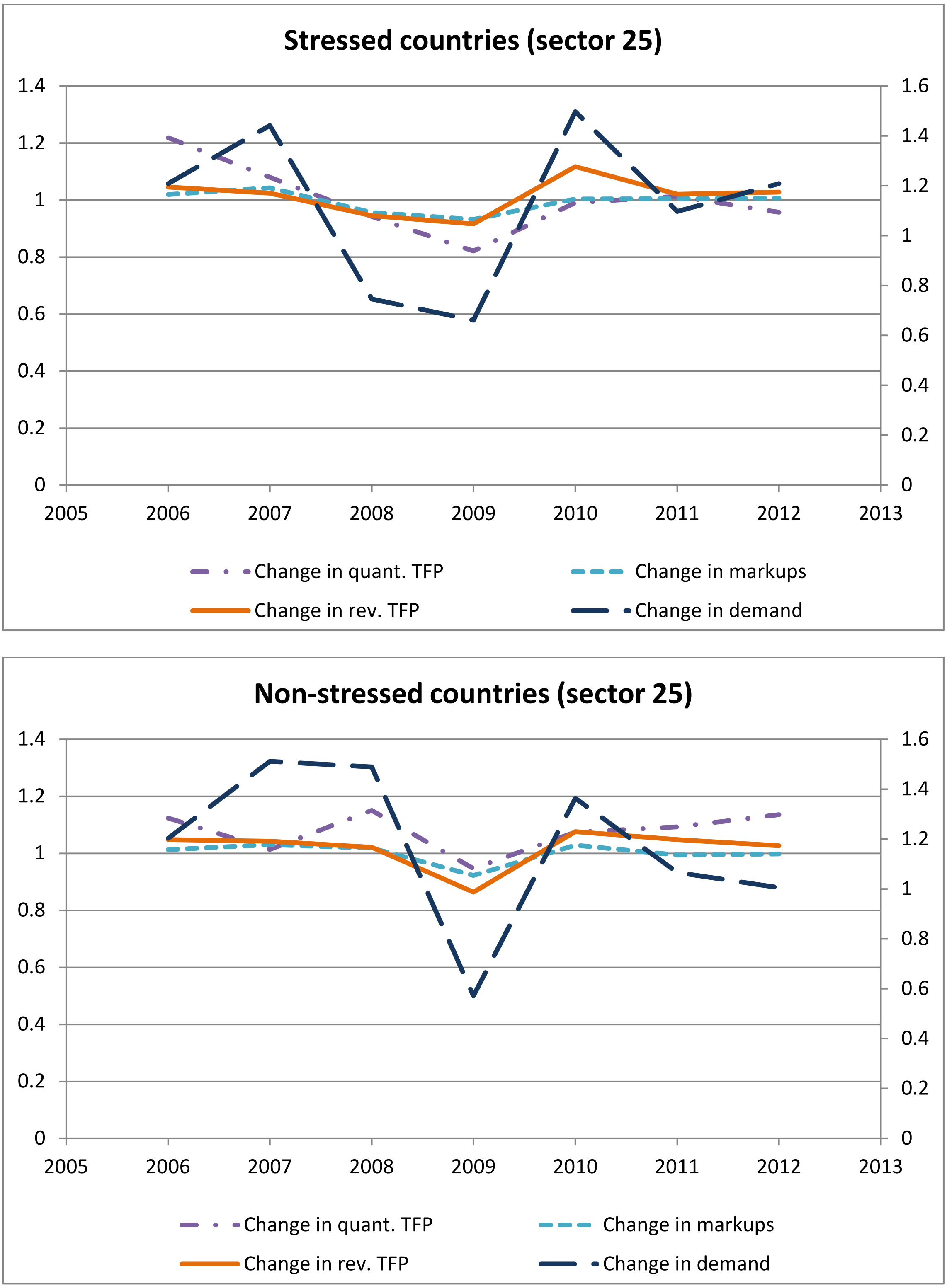
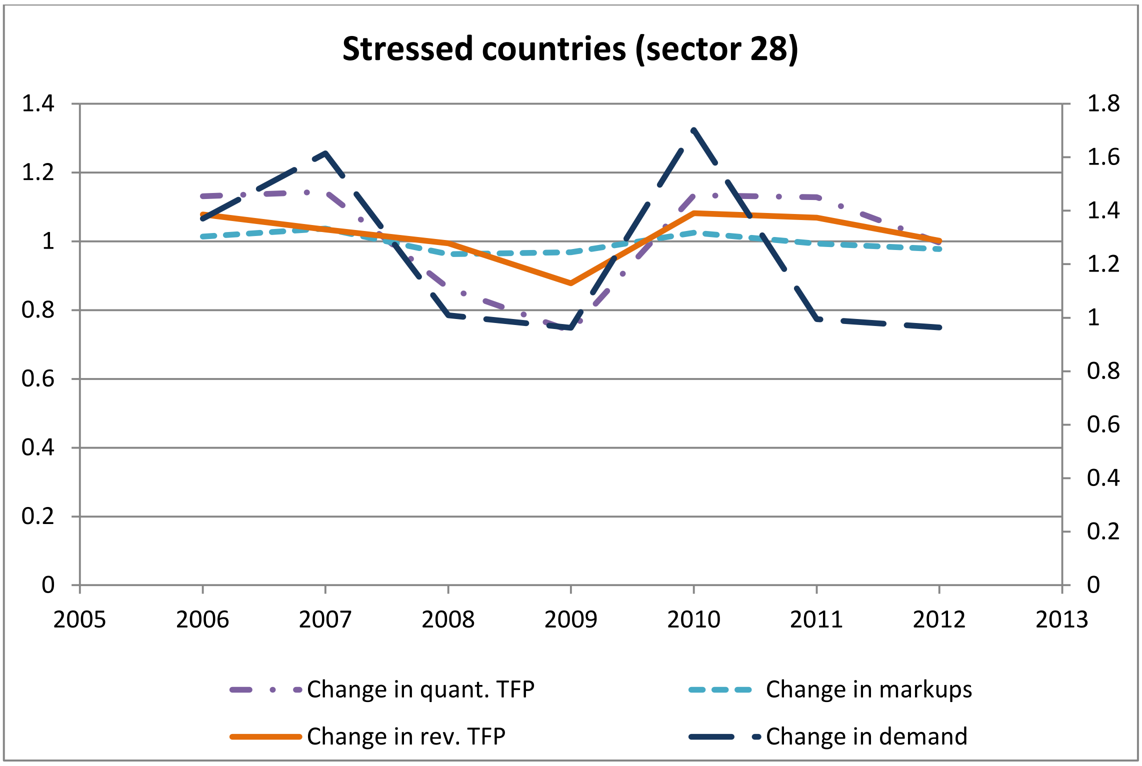


Figure 7: TFPR and corresponding decomposition for sector 25; stressed countries



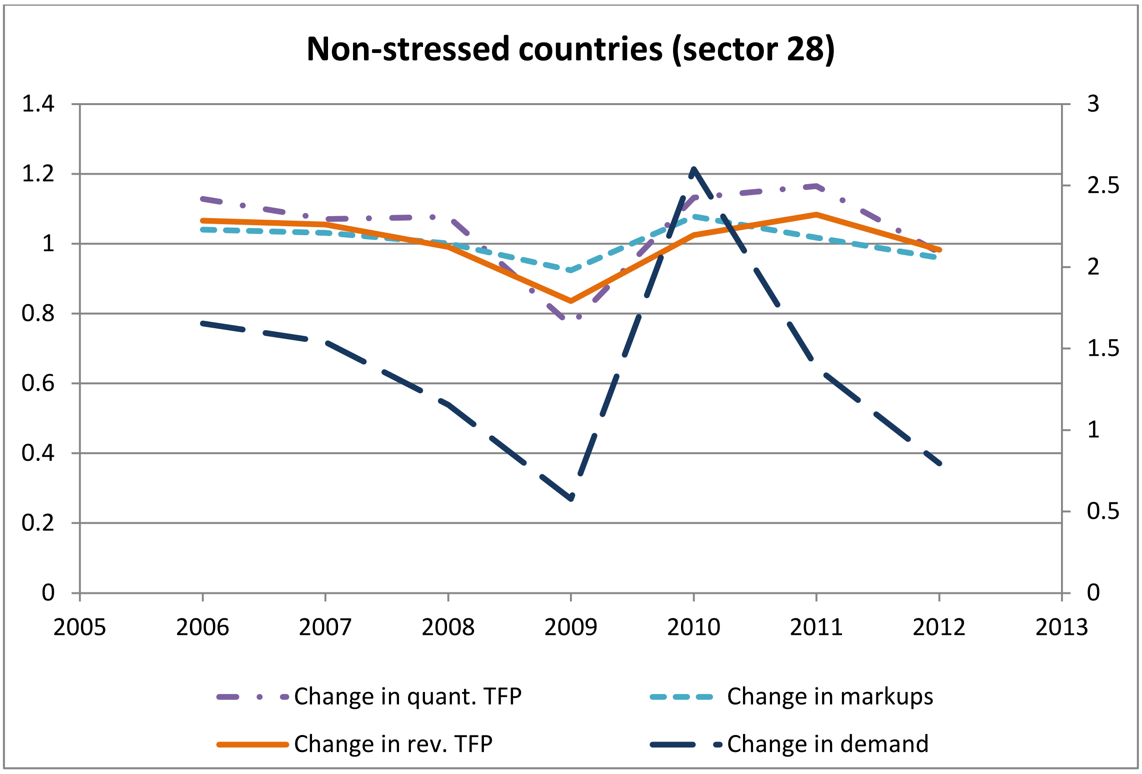


Figure 8: TFPR and corresponding decomposition for sector 28; non-stressed countries

5. Conclusions

In this paper we derive a methodology to decompose *aggregate* revenue TFP changes over time and apply it to a panel of EU countries and manufacturing industries over the period 2006-2012. Our methodology builds upon Forlani et al. (2016) with revenue productivity being in our framework the outcome of underlying differences and evolution of physical TFP, mark-ups, quality and production scale.

The main insights of our analysis might be summarized as follows. First, we find that similarities between stressed and non-stressed countries in the wake of the recent crisis are more pervasive than differences. Second, despite a fall in revenue productivity of 'only' about 6% in both country groups there have been behind the scene much more substantial changes in underlying fundamentals like demand and quantity TFP to which firms have reacted by almost equally substantial counter-actions working via the mark-ups and inputs use margins. Moreover, the results suggest that demand-changes have been the main driver for cross-sector differences in sectoral TFPR trends.

In terms of where these countries stand as of 2012 the overall picture that emerges from our analysis is one in which non-stressed countries seem to enjoy a stronger recovery in terms of fundamentals like quantity TFP, demand and mark-ups than stressed countries. Yet their overall performance in terms of revenue TFP recovery does not necessarily align with the above analysis. The reason for this has to do with some features of our framework that can be interpreted as a worsening of the misallocation of resources.

In terms of directions for future research we endorse future studies looking at firms rather than products as well as including material inputs into the TFP analysis. We believe such studies would allow bringing the analysis forward by gaining further insights into the quantity TFP and demand collapse as well as into the extent of change in resources misallocations.

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