Unwrapping TFP

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Abstract

In this paper we study the long-run determinants of Total Factor Productivity (TFP) in three major European economies over the period 1980-2016. We focus on the capital misallocation effects, scale effects and labor misallocation effects. A stripped-down model of labor market in open economy with techonology progress allow us to identify the relevant variables affecting TFP. On the empirical ground, we find a positive relationship between TFP and real interest rate in the long run. Importantly, we detect an ambiguous relationship between TFP and real exchange rate. Further, we illustrate that the TFP responds positively to a stricter labor market regulation and to a higher real compensation per employee. Our results provide support to the idea that TFP has a positive relation with input prices in the long run, while it may be biased along the cycle because of price rigidity. These results are obtained using a VAR model for estimation.

Keywords: TFP; interest rate; exchange rate; labor market deregulation.

JEL classification: C22, D21, D24.

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1 Introduction

Total factor productivity (TFP) is the exogenous residual that results from subtracting the contribution of inputs to output growth (Solow, 1957). In traditional macroeconomic models it proxies the technology progress. Innovation, human capital and knowledge are the sources of TFP and the main engines of economic growth (Romer, 1994). Still, a shared theory of TFP does not exist. TFP may be affected by market imperfections. Azariadis (2016*a*, 2016*b*) shows, for example, that with imperfect capital markets TFP performs well when equities are owned by productive firms. Similarly, Kaas (2016) argues that a long-run equilibrium can be characterized by the coexistence of low interest rate and TFP because the less efficient firms succeed in surviving at the lower capital cost. This adverse combination can eventually result in capital misallocation. Accordingly, Cette *et al.* (2016) assert that the decreasing pattern of the real interest rates in Europe, from 1995 to 2008, explain the pre-great slowdown in productivity of the continental European economies. In their view, the decreasing of the interest rates until 2008 contributed to cut the user cost of capital allowing the less competitive firms to keep producing. Thus "if resources are shifting toward lower marginal product uses, then misallocation can get worse and aggregate TFP could fall" (Cette, et al. 2016, p.10).

The present study focuses on these controversial issues. We test if changes in input prices can cause asymmetries in TFP among countries because of the misallocation of capital and labor. Among the European countries, Germany and Italy are the polar cases of these asymmetric patterns. Traditionally, asymmetries can be caused by monetary shocks in interest rate and exchange rate (Lane, 2006). Further, the recent literature has stressed the relationship between TFP and labor market regulation. Mainly, labor de-regulation has been criticized for the following reason: By reducing the hiring and firing costs of labor it may boost firms to postpone investment and innovation, resulting in the long-run fall of capital intensity and productivity (Saltari and Travaglini, 2006, 2009; Gordon and Drew-Becker, 2008; Pessoa and Van Rinen 2014; Calcagnini *et al.*, 2017)

Accordingly, we study the effects of changes in monetary and institutional variables on the TFP of three major European countries over the period 1980-2016. There is a large disputed literature on this issue. Among these studies, the most recent references to our paper are Cette *et al.* (2016), Gopinath *et al.* (2017) and Bagnai and Mongeau-Ospina (2017).

We have already pointed out the contribution by Cette *et al.* (2016). Let's briefly focus on the other two papers. Gopinath *et al.* (2017) illustrate how, along the more recent years, the decrease in the real interest rate leaded to a significant decline in sectorial TFP of European countries. In response to the interest rate decrease, capital was misallocated toward firms with lower productive performance, but with higher market's value. Accordingly, Bagnai and Mongeau-Ospina (2017) argue that changes in the real interest rate may affect labor productivity. However, they sustain that changes in the real exchange rate have negative impacts on labor productivity.

In what follows we discuss these findings. To this aim we present a stripped-down labor market model with technology progress, real exchange rate and labor regulation. Then, we use a linearized version of it to estimate a VAR model and test its predictions. Mainly, and in contrast with a part of the literature, we find a positive long-run relationship between TFP and real exchange rate. Further, TFP responds positively to a stricter labor market regulation, to a higher real wage and to a higher real interest rate. Therefore, our evidence shows that TFP has a positive relationship with prices in the long run, while it may be biased transitory along the cycle (negative effects) because of price rigidity and labor market stickiness.

The paper is organized as follows. Section 2 offers a brief literature review. Section 3 develops a baseline model of labor market and TFP determinants. Section 4 presents stylized facts and the database. Section 5 develops the econometric framework with the empirical results. Section 6 concludes.

2 Literature

In the last two decades the TFP growth rate has been slowing down in European countries. Many recent contributions focus on these issues.

At sectorial level, Melitz (2003) shows that productivity differences provide useful informations about the heterogeneity of industries. He argues that the existence of persistent performance differences among similar firms (and countries) is well established so that the most recent studies in trade, industry and productivity have increasingly taken this stylized fact as a fundamental starting point. However, the question of what causes these differences is still an open question. Accordingly, Syverson (2011) analyzes the large differences in productivity within industries. He interprets productivity as a heterogeneous input of production crucially affected by differences in management practice, higher quality labor and capital, differential investment in ICT.

At country level, Gordon and Dew-Becker (2008), and Saltari and Travaglini (2009) study the relationship between productivity, capital accumulation and technology progress. Mainly, they address the question of whether labor supply shifts are the only source of the productivity slowdown among the main industrialized countries, over the last decades. It would imply that labor demand shifts are irrelevant to explain the labor-productivity trade-off. Using a simple model of labor market, they show that the poor economic performance of many European countries can be accounted for by a combination of two shocks: an adverse technology shock to the labor demand and a positive non-technology shock to the labor supply resulting from changes in institutions. In brief, while technology shocks can explain the productivity slowdown, but not the changes in employment, non-technology shocks can capture changes of employment, but not the slowdown of productivity. Therefore, both shocks are necessary to provide a complete picture of the relationship between productivity and employment.

This issue has been recently studied by Pessoa and Van Reenen (2014). For the British economy, they find that the fall of labor productivity since 2008 is likely due to the decrease in capital intensity. This occurred because of the fall in real wages as a consequence of labor market deregulation. Accordingly, Cacciatore and Fiori (2016) analyse the macroeconomic effects of deregulating the goods and labor markets by means of endogenous product creation and labor market frictions in an otherwise-standard real business cycle model. They find that (de)regulation affects producer entry costs, firing restrictions, and unemployment benefits, with short-run recessionary effects, despite being expansionary in the long run.

A further strand of research pivots on the pattern of real interest rates to explain how their decrease, prior to 2008, influenced the slowdown in productivity of continental European economies. As said above, Cette *et al.* (2016) focus on this issue. They sustain that the falling real interest rates and the sluggish ICT diffusion in the southern European countries were the consequences of the economic convergence started with the monetary union. Precisely, they pointed out that the monetary union and ICT diffusion required a deregulation of labor and product markets that inhibited the development of more efficient technologies causing the slowdown in TFP.

Accordingly, Gopinath *et al.* (2017) observe that, from early 1990s, countries in southern Europe experienced low productivity growth alongside declining real interest rates. Using data from manufacturing sector in Spain, they illustrate how the decline in the real interest rate, often attributed to the euro convergence process, leads to a significant decline in sectorial TFP as capital inflows are misallocated toward firms that have higher net worth, but are not necessarily more productive. They also observe similar trends in dispersion and productivity losses in Italy and Portugal, but not in Germany, France, and Norway, thereby establishing an asymmetry between northern and southern European economies

In this vein, Bagnai and Montegeau-Ospina (2017) study the productivity slowdown in the euro area using panel data by industrial sectors, concluding that monetary unification have fostered divergence in productivity trends. They detect the presence of real and financing sources of potential divergence in labor productivity with a crucial and negative role played by the real exchange rate.

To summarize, the current literature identifies at least three sources of shocks which may contribute to explain the observed productivity and TFP asymmetries among the major European countries. Specifically, we refer to:

Capital misallocation. It states that a decreasing *real interest rate* can boost firms to postpone investment and innovation, undermining TFP in the long run. Recent TFP slowdown in southern European countries can be explained by capital misallocation, with its aggregate effect on the single economies (Reis, 2013; Benigno and Fornaro, 2014; Cette *et al.*, 2016; Gopinath *et al.*, 2017);

Scale effect. It has two declinations. On the one hand, it captures the role of the real *exchange rate* in affecting external demand and productivity growth (Verdoon, 1949; Kaldor, 1966). Accordingly, an overvalued (devaluated) currency may reduce (increase) the scale of production and the aggregate demand of an economy affecting negatively (positively) the productivity growth (Ostry, 1995; Rodrick, 2008). Importantly, the relationship between exchange rate and TFP varies greatly across sectors and countries, depending on the structure of the economy and the competitiveness degree of its markets (Tomlin and Fung, 2010). Thus, the "scale effect" is referable to the *demand-side* view of the real exchange rate appreciation (depreciation) on TFP. On the other hand, a *supply-side* view stresses the positive and long lasting consequences of a real exchange rate appreciation on productivity and TFP. Precisely, it implies that a "hard" real exchange rate can contribute to raise productivity and competitiveness in the long run (Porter, 1990);

Labor misallocation. It focuses on the role of labor market regulation in affecting investment, innovation and TFP (Bassanini, 2009; Calcagnini et al., 2018). The current debate identifies at least two main opposite effects. On one hand, labor regulation may increase the firms' labor and investment adjustment costs decreasing innovation and investment (Bentolila and Bertola 1990; Layard, Nickell, and Jackman 1997; Nickell and Layard 1999; Bartelsman, Gautier, and DeWind 2016). On the other hand, a stricter labor regulation may stimulate firms to invest and innovate to recover rents, affecting positively TFP in the long run (Acemoglu 1998; Blanchard 2000; Griffith and Macartney 2014; Pessoa and Van Reenen 2014). We will focus on these contrasting sources to study how TFP growth responds to changes in labor market regulation and real compensation.

To this aim, we present a basic labor market model in open economy with TFP and regulation. Then, we develop a VAR model for three major European countries, namely France, Germany, and Italy, over the period 1980-2016. The long-run relationship between TFP, real interest rate, real exchange rate, labor market regulation and real wage are studied. Our main result is to show that an increase in real exchange rate and real interest rate can cause a persistent increase in TFP.

3 The model

We use a basic labor market model in open economy to explain our view. It builds on Layard *et al.* (1997), Blanchard (2013) and Carlin and Sosckice (2015).

We start with the *price-setting* rule. The existence of a markup implies that the (real) productivity a is greater than the marginal cost $\frac{W^{PS}}{P}$ by a factor equal to the markup, that is

$$a = \frac{W^{PS}}{P} (1 + \mu_0 + \mu_1 r) \tag{1}$$

As in Layard *et al.* (1997), the markup $(1 + \mu_0 + \mu_1 r)$ tends to raise with the level of activity, proxied by the real interest rate r, with μ_0 the independent component of markup, and μ_1 the variable component of it affected by the level of activity. Then, the prices P of national goods are set as a markup on nominal wage W^{PS} (the firms are willing to pay) measured in effective units

$$P = (1 + \mu_0 + \mu_1 r) \frac{W^{PS}}{a} \tag{2}$$

Equation (2) states that each worker produces a units of output. Put another way, producing one unit of output requires $\frac{1}{a}$ workers. If the nominal wage is equal to W^{PS}, the nominal cost of producing one unit of output is therefore equal to $\frac{W^{PS}}{a}$. So, an increase in productivity decreases costs, which decreases the price level of national goods, given the nominal wage the setters are willing to pay. We use total factor productivity (TFP) to proxy a, the measure of productivity.

In an open economy workers consume both domestic and foreign goods in some proportion. Thus, real wages depend on a composite price index P_c which includes prices of those domestic and foreign goods. Foreign goods have price P^*, while domestic goods have price P. The share of the foreign goods on total consumption is $\gamma \in (0, 1)$. Hence, the consumer price index can be written as

$$P_c = (1-\gamma)P + \gamma \frac{P^*}{E} \tag{3}$$

where E is the nominal exchange rate defined as the price of the domestic currency in terms of the foreign currency. An increase (decrease) in the nominal exchange rate E is an appreciation (depreciation) of the domestic currency in terms of a foreign currency. Define the real exchange rate as $\varepsilon = \frac{EP}{P^*}$. Substituting (2) in (3), using the approximation that $\frac{1}{1+x} \simeq 1 - x$, and solving for the real wage $w^{ps} \equiv W^{PS}/P_c$ we get

$$w^{ps} = \frac{a\,(1-\mu_0-\mu_1 r)}{1+\gamma(\varepsilon^{-1}-1)} \tag{4}$$

where w^{ps} is the real wage that the price-setters are willing to pay. This can be approximated by

$$w^{ps} \simeq a\,(1-\mu_0-\mu_1 r)\left[1-\gamma(\varepsilon^{-1}-1)\right] \tag{5}$$

so that the relation between w and ε is

$$\frac{dw^{ps}}{d\varepsilon} \simeq a\,(1-\mu_0-\mu_1 r)\,\gamma\varepsilon^{-2} > 0$$

The price setting rule implies that the real wage w^{ps}, the firms are willing to pay, is positively related to the real exchange rate ε. Indeed, if imported goods become more expensive – that is, if ε decreases, either because the foreign price P^* raises or the nominal exchange rate E depreciates – consumption bundles become more expensive, reducing the real wage of workers.

Thus, given the price of imports and the nominal exchange rate, the price to consumers varies with the real exchange rate.

Turn to *wage-setting*. A decrease of the unemployment rate u, and a stricter labor market regulation – measured by the catchall variable z – is associated with a raise in the nominal wage demanded by workers. Further, in an open economy, under the assumption of *Nash bargaining* in labor market, the demanded nominal wage increases of a proportion $\lambda\varepsilon$, where $0 \leq \lambda \leq 1$ denotes the relative bargaining strength of workers to defend the real wage. The evidence also suggests that, other things being equal, wages are typically set to reflect the increase in productivity a over time. This suggests the following extension of the wage-setting rule

$$W^{WS} = P_c \left[z - \beta u + \lambda \left(\varepsilon + a\right)\right] \tag{6}$$

or

$$w^{ws} = z - \beta u + \lambda\varepsilon + \lambda a \tag{7}$$

where $w^{ws} \equiv W^{WS}/P_c$ is the real wage demanded by workers. Wages now depend on the level of both productivity and real exchange rate. If workers and firms both expect productivity and real exchange rate to change, they will incorporate those expectations into the wages set in bargaining.

We can now characterize the equilibrium in labor market. It requires $w^{ps} = w^{ws}$. However, solving for a we get an endogenous relationship for the TFP in equilibrium

$$a = \frac{z - \beta u + \lambda\varepsilon}{\left(1 - \mu_0 - \mu_1 r\right)\left[1 - \gamma(\varepsilon^{-1} - 1)\right] - \lambda} \tag{8}$$

Equation (8) states that, in equilibrium, the level of TFP is positively affected by the variable z (a measure of the labor regulation). Also, the level of TFP tends to decrease as the unemployment rate u raises, and to increase when the interest rate r raises. Notice that capital misallocation can emerge when r decrease steadily. Finally, equation (8) also says that the markup components μ_0 and μ_1 have a positive long-run impact on the TFP. We label this relation as a *Schumpeterian effect* because, as Schumpeter argued (1961), economic growth revolves around innovation, market power and entrepreneurial activities.

More controversial is the relationship between TFP and real exchange rate in equilibrium (long run). It is formally captured by the derivative

$$\frac{da}{d\varepsilon}=\frac{1}{(1-\lambda)(1-\mu_0-\mu_1 r)}\frac{\lambda\left[1-\gamma(\varepsilon^{-1}-1)\right]-\gamma\varepsilon^{-2}(z-\beta u+\lambda\varepsilon)}{\left[1-\gamma(\varepsilon^{-1}-1)\right]^2}\gtreqless 0 \quad (9)$$

According to (9) its sign depends on the values of the parameters which characterize the *price-setting* and *the wage-setting* rules: for example, a high value of λ, compared to the share of foreign goods on total consumption γ, raises, in a bilateral negotiation, the average strength of firms to innovate in order to recover productivity and competitiveness in the long run (Calcagnini *et al.*, 2018). But, the level of productivity depends on both technology and real exchange rate. Of course, the latter "scale effect" refers to the *supply-side* view of the real exchange rate appreciation (depreciation) on TFP. It means that an increase (decrease) in ε also contribute to raise (decrease) productivity improving firms' competitiveness. This is actually an old idea which explains why a country would prefer a "hard currency" instead of a weak currency (Harris, 2001). Indeed, as Porter (1990) pointed out depreciations can reduce productivity over time, whereas an overvalued real exchange rate can sometimes contribute to raise productivity and competitiveness by forcing innovation and technology progress in tradeable sectors.[1]

By obtaining estimates of equation (8) we study the fit of our model. Empirically, how well does it explains the observed pattern of TFP? A linearized version of equation (8) is employed to run the empirical analysis. Importantly, in our empirical analysis the gross national saving is used to control for the independent markup component μ_0. Indeed, as shown by *Galì (1994, 1995),* in imperfectly competitive markets, as it is the case in our model, the level of saving determines the long-run level of capital stock per worker, the corresponding productivity and the market power of firms.

Equation (8) gives some *a priori* about the causal relationships between the TFP and the explanatory variables. In the long run, the relationship between real interest rate and TFP is positive: an increase r tends to raise the level of a. Ambiguous, instead, is the relationship with the real exchange rate ε. Further, notice that the price setting rule (4) states the existence of a positive relationship between a and w (but also a *reverse* causation between

[1] Singapore, for example, had a long period of deliberate appreciation of the exchange rate with a stated intention of forcing competitive productivity increases (Lu and Yu 1999).

them). Finally, from equation (8) emerges that a higher value of z (a stricter labor regulation) tends to raise the TFP to recover productivity and competitiveness in the long run. Analogous algebraic sign has the "Schumpeterian" link between a and the markup components.

Therefore, the main implication of our stripped-down model is that a higher level of both real interest rate and labor regulation can push up TFP just as more innovation and investment can stimulate labor productivity in the standard neoclassical growth model. The two processes are strictly related. However, ambiguous remains the impact of changes in the real exchange rate on the TFP. Hence, in our model there are scenarios where lower interest rates, lower exchange rates and more flexible labor markets can depress technology progress, slowing down productivity instead of raising it in the long run.

4 Database and Stylized Facts

We are interested in studying the determinants of the TFP in the major three European countries, namely Germany, France, Italy. Dataset relies on the European Commission AMECO database, over the period 1980-2016. Our data provides information on:

1. *TFP*. It measures the difference between the contribution of the real output (GDP) and the capital intensity weighted by capital share. It is expressed as an index, with $2010 = 100$. TFP takes into account the impact of any technology factor switching the production function in the long run;

2. Real effective exchange rates, ER. It provides comparable measures of euro area countries' price and cost competitiveness. Its value depends on the nominal exchange rate and on the prices of national and foreign goods exchanged in the international markets. Thus, ER provides a measure of the performance of any single economy relative to the rest of the main European countries;

3. Real long-term interest rates, IR. It is a measure of the user cost of capital and captures the effects of capital misallocation on TFP. As noted by Cette *et al.* (2006), a low real interest rate can allow the less competitive firms to survive in the market, reducing innovation and

TFP in the long run. In our empirical model, the user cost is proxied by the interest rate on long-term government bonds. Therefore, IR is the price of the intertemporal allocation of resources, and its evolution determines investment and TFP along time;

4. Real compensation per employee, RC. It captures the impact of labor cost on TFP. The AMECO database uses a domestic concept of real compensation, including residents as well as non-residents working for resident producer units. Compensation includes not only wages and salaries, but also social contributions;

5. Incidence of temporary employment for young workers, ITE. It refers to standardized age group 15-24 of the OECD statistics and captures changes in labor market regulation. Hence, ITE provides a measure of the impact of changes in labor market regulation (the parameter z of the theoretical model) on TFP. Following Calcagnini *et al.* (2017), we assume that higher is labor flexibility higher is the share of temporary workers employed in production by firms.

6. Gross national saving, S. As said above, we use aggregate saving to proxy the autonomous markup component μ_0. The Ameco database provides data for saving starting from disposable income. Following Galì (1994), we assume that with imperfect competition the markup variations are related to changes in saving accumulation. These changes determine the long run dimension of the economy, the steady state, and, eventually, the market power of firms.

In what follows, variables used in the empirical analysis are in logarithm, with the exception the real interest rate and the incidence of temporary employment on total employment. We can interpret the value of the estimated parameters as elasticities. Descriptive statistics of data are reported in Table 1. They are controlled for the so called "great recession" of 2008 by using dummy variables.

Table 1. **Descriptive statistics.**

	TFP	IR	ER	RC	ITE	S
Mean	4.55	3.25	4.61	4.51	4.05	5.66
Median	4.57	3.35	4.60	4.54	4.52	5.68
Maximum	4.66	8.53	4.89	4.69	6.19	6.79
Minimum	4.36	-4.60	4.34	4.29	1.14	4.39
Std. Dev.	0.08	2.15	0.09	0.09	15.5	0.54
Skwness	-0.73	0.40	0.07	-0.48	-0.63	-0.13
Kurtosis	2.38	3.68	3.65	2.22	2.10	2.52
Jarque-Bera	12.2	5.29	2.12	7.36	10.4	1.40
Probability	0.03	0.07	0.34	0.03	0.01	0.54
Sum	518.2	370.3	526.1	514.6	421.9	646.8
Sum Sq. Dev	0.734	5.22	1.012	1.122	2.50	33.52
Observation	114	114	114	114	114	114

Source: Ameco database.

Figure (1) shows the graphs of the variables under investigation. The inspection of the figures provides information about their divergence or convergence over time in the three countries under investigation. Mainly, while Italy and France show a decreasing TFP path from the beginning of 2000, Germany shows a raising path, even after the economic crisis of 2008. Notice that the the real exchange rates follow an asymmetric path until 2010. They become more stable hereafter. Same asymmetries characterize the pattern of real wages, temporary employment (raising in all countries) and savings. Only the real interest rates have a common trend although exhibit a raising volatility during the period 2008-2014.

5 Estimation results

In this section we present our vector autoregressive model (VAR) for three major European economies under investigation, namely Germany, France and Italy. The impact of five shocks in TFP, real exchange rate, real interest rate, real wage and the index of temporary employment are analysed. Further, we compare the observed responses of our variables, along time and among

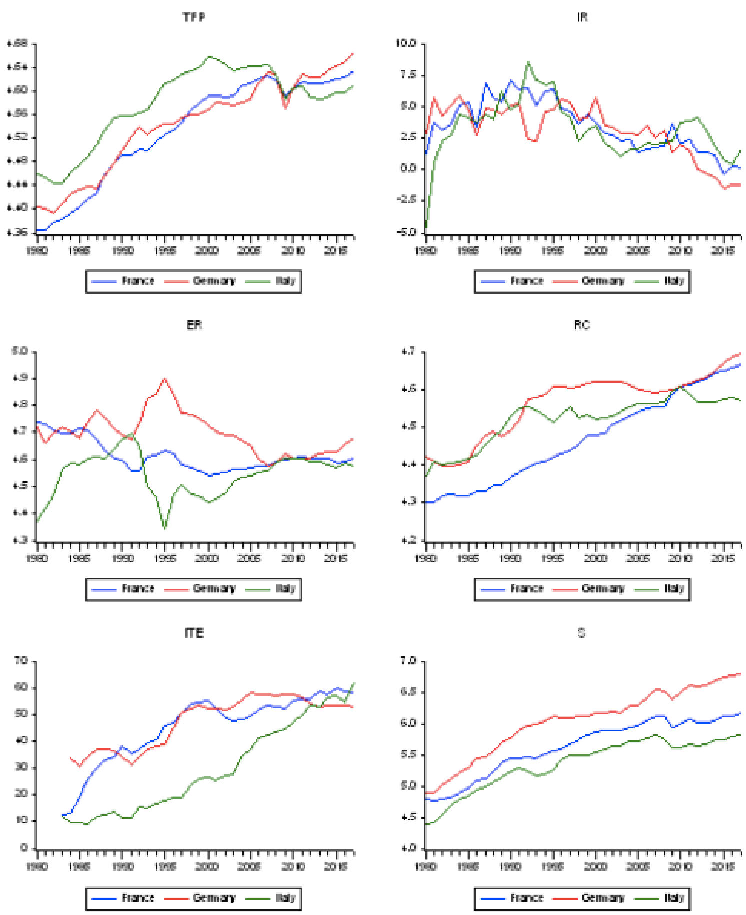

Figure 1: The economic variables (Ameco database).

them, in order to check their consistency with the prediction of our theoretical model.

Our approach is essentially empirical. We employ a VAR model without imposing any a priori restrictions. We only limit our analysis to use the type of the recursive system proposed by Sims (1980), that is decomposing the VAR residuals in a triangular fashion, also known as Cholesky decomposition (Cette *et al.* 2016). However, given that we are interested in the response of TFP to some variables, we focus on the effects of shocks to TFP after allowing for contemporaneous and past shocks in the real and institutional variables considered in our model. Specifically, this ordering constraints the TFP to respond to shocks in real exchange rate only with a lag. In contrast, the other variables response immediately to the real exchange rate (demand effect) but not to the TFP shock (supply effect). From our empirical analysis emerges that the qualitative responses are similar across alternative treatments of the deterministic components.

The first step consists in estimating a basic VAR system which include the following variables for the period 1986 to 2016: total factor productivity (a), real effective exchange rate (ε), real long-term interest rate (r), real compensation per employee (w), incidence of temporary employment (z).

Let's x be the data vector with dimension 5x1 for each period t and $x = [a, \varepsilon, r, w, z]'$. The VAR model is

$$x_t = c + B_1 x_{t-1} + \ldots + B_p x_{t-p} + e_t \tag{10}$$

where e_t is a 5x1 vector of reduced-form shocks, B_p is a 5x5 matrices of coefficients, and c is a 5x1 vector of intercepts. Consistent estimates of the VAR parameters can be obtained by ordinary least squares. Then, we derive the impulse response functions (IRFs) showing the response of all variables to each reduced-form shock. To relate reduced-form to structural shocks, we assume that the structural model for x_t is of the following form:

$$A_0 x_t = c^{'} + A_1 x_{t-1} + \ldots + A_p x_{t-p} + \varepsilon_t \tag{11}$$

where ε_t is a five-dimensional vector of orthogonal structural shocks, $c^{'}$ is a vector of intercepts and A_p are matrices of coefficients. Pre-multiplying (10) by A_0 and relating the resulting equation to (11), we obtain the following correspondence between the reduced-form and structural shocks

$$A_0 e_t = \varepsilon_t \tag{12}$$

There are several ways to recover the parameters in the structural form equations from the estimated parameters in the reduced form equation (11). A popular method is to orthogonalize the reduced-form disturbances by Cholesky decomposition imposing $n(n-1)/2$ restrictions on the variance covariance matrix (Sims, 1980). Cholesky decomposition is achieved by making restrictions on the A_0 matrix itself by imposing some of its elements to be zero, that is, by turning off some of the contemporaneous correlations between the different variables. Indeed, if A_0 is assumed to be lower triangular, then

$$A_0^{-1} = chol(\Omega) \tag{13}$$

where $chol(\Omega)$ denotes the Cholesky decomposition of the covariance matrix Ω of the residuals in the reduced-form VAR. These restrictions on the contemporaneous correlations of the errors are enough to recover unique estimates of the fundamental shocks from the VAR residuals. However, this triangular fashion implies the existence of a recursive structure. Therefore, we proceed ordering our variables by means of an exogeneity criterion. Precisely, we use theoretical assumptions derived from our model to suppose that one variable has contemporaneous effect on the others. Consistently with our theoretical model we put first the most exogenous among our variables, then the second one, and so on (i.e. TFP, real exchange rate, ITE, real compensation and the real interest rate). The last variable is the one for which all the other variables have effect on it.

5.1 Impulse responses

We begin our empirical analysis estimating the unrestricted VAR system with one lag for each variable of the five equations. A considerable amount of literature shows the advantages of using unrestricted VAR by examining IRFs in cointegrated systems (Naka and Tufte, 1997). In addition, a number of studies have shown that unrestricted VARs are superior in terms of forecast variance (Engle and Yoo, 1987; Clements and Hendry, 1995; Hoffman and Rasche, 1996).

A way to study the short and long-run responses of a VAR model is to compute its IRFs. The impulse responses trace out how the shocks in one of the variables impact on current and future values of the other variables in the model. Then, if the system of equations is stable, any time series tends to converge towards the (new) steady state after the initial shock.

The IRFs are built from inversion of the VAR model, *via* the Wald transformation to a moving average representation. The advantage of the impulse response functions is that they allow "shock accounting". To run the procedure, we set all initial values to zero and shock one of the variables to a unit value at time zero. The response function indicates what happens to the system in succeeding periods if no further shocks occur. We use the Cholesky ordering as specified above.

The correct lag length selection is essential for VAR specification, having lags which are too short fails to capture the system's dynamics. Indeed, having too many lags causes a loss of degrees of freedom, resulting in overparameterization. Based on the minimized values of the respective information criteria (Akaike, the Bayesian criterion of Schwartz and Hannan-Quinn), we use one lag for each model. Then, IRFs and variance decompositions (VDCs) are computed. The solid line in figure (2)-(7) describes the impulse response of any single variable to an initial one-standard deviation shock. Shaded area represents the 90% bootstrap confidence interval around the point estimates. The errors of the IRFs are computed by simulation using 1000 replications of the model, and the shaded area equal the point estimates of the IRF plus or minus 1.645 times the simulated standard error. The horizon is given on the horizontal axis. The computed IRFs provide outcomes coherent with the structure of our theoretical model.

5.1.1 Responses of TFP to shocks

The response of TFP to shocks is the main issue of our analysis. According to the theoretical model we expect to find a positive relationship between TFP and the interest rate, the (variable) markup and the labor regulation. Again, evidence on the relationship between TFP and real exchange rate could be mixed, since the global effect of a real exchange shock on the TFP depends on the magnitude of the parameters which characterize the price-setting and the wage-setting rules. TFP responses to shocks are shown in fig.(2) fig.(3) and fig. (4).

From the IRFs emerges that in Italy and Germany the TFP reacts positively to shocks in real wages and real exchange rates, both in the short and long run. This means that when these shocks take place the value of technology progress tends to increase affecting positively the productivity in the long run. For Italy, we find that the responses of TFP to a real wage

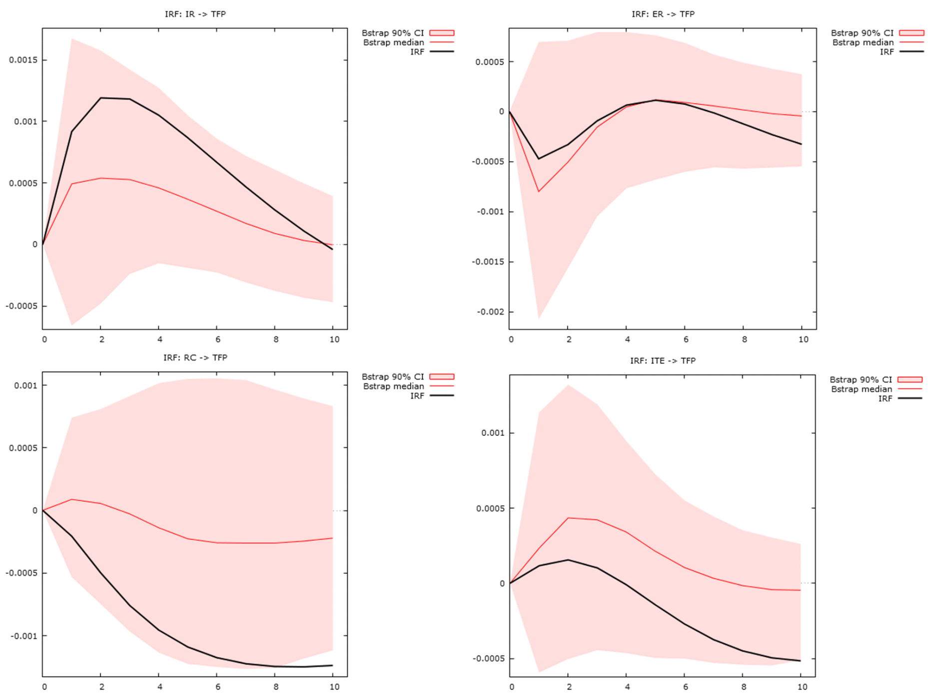

Figure 2: Italy: TFP responses to shocks.

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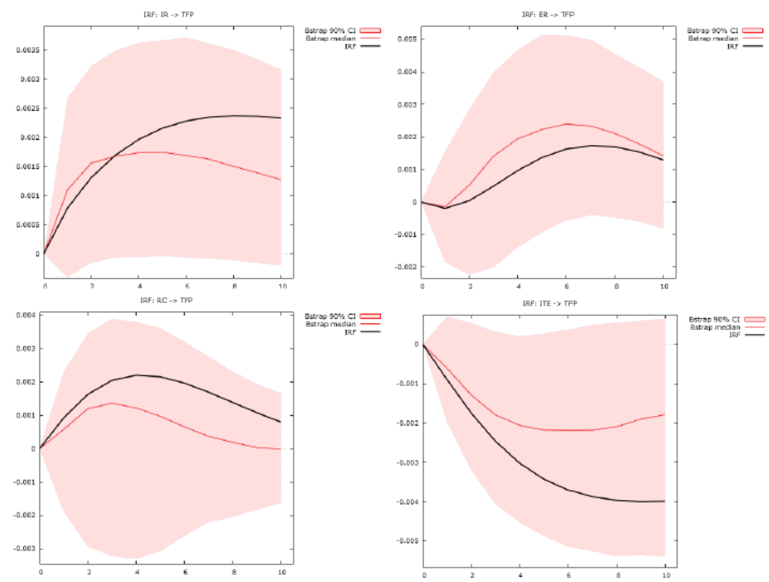

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Figure 3: Germany: TFP responses to shocks.

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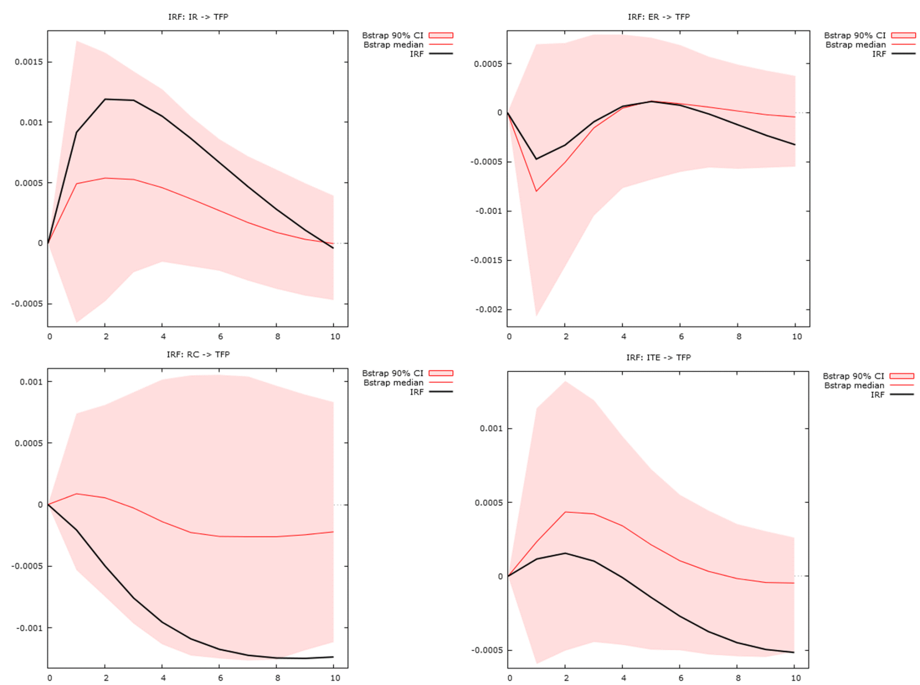

$_4$.*pdf*

Figure 4: France: TFP responses to shocks.

shock shrinks sharply, then gradually increases with a full positive response in about 4 years. The response of the TFP for the German follows an analogous path. Conversely, in France the real exchange rate shock has a negative (if any) impact on the TFP, where a new steady state is reached after about 6 to 7 years.

Importantly, much more homogeneous is the response of TFP to a shock in labor market regulation (proxied by ITE). Specifically, a positive shock in ITE (which means a higher flexibility in labor market) decreases steadly the TFP in the three economies. Conversely, less homogeneous is the response to a shock in real wage (RC). Indeed, in Italy and Germany, the RC shock has a positive effect on the TFP, meaning that firms tend to invest and innovate to recover rents along time. Negative is instead the relationship between real wage shock and TFP in France.

5.1.2 Reverse causation.

Figures (5) fig.(6) and fig. (7) illustrate the responses of ER, IR, RC and ITE to a TFP shock.

In line with the theoretical model, we estimate a global negative impact of a TFP shock on the real exchange rate ER. In France and Germany, the impact tends to be positive only in the short and medium run. But this initial effect disappears as time passes. Contrariwise, in Italy the shock has a large negative impact on the real exchange rate.

Then, a TFP shock also affects permanently the temporary employment ITE. More precisely, in Italy and Germany, after an initial decrease, ITE tends to increase in the long run. In France the relation between TFP shock and ITE is positive.

Also, in all countries real compensation RC reacts positively to a shock in TFP. However, the IRFs illustrate an initial negative impact, particularly marked in France. Overall, in Italy the response of the real compensation to a TFP shock is larger than in Germany and France.

Finally, the real interest rate IR responses to a TFP shock are heterogeneous. It increases at all frequencies in France, decreases in Italy, and it is substantially stable in Germany, where after an unitial overshooting it decreases in the short run.

To resume, the findings of our VAR model provide evidence in favor of the "capital" and "labor misallocation". This adverse process may explain the observed asymmetries in TFP of the three economis under consideration.

Note that, from our analysis also emerges that in Italy and Germany the long-run elasticity of TFP to the real exchange rate ER is *positive*. Less relevant, but basically negative, is the impact in France.

Thus, what can we conclude? Firstly, a positive relationship between TFP and real exchange rate can exist and characterize the economic growth. More precisely, we can claim that technology progress is not *necessarily* crowed-out by a "hard" real exchange rate, as asserted by the *demand-side* view of the real exchange rate appreciation (Verdoon, 1949). For this reason, our evidence provide some support to the *supply-side* view of the real exchange rate according to which an overvalued exchange rate can contribute to improve productivity, instead of reducing it, by forcing technology progress and innovation in the long run (Porter, 1990).

Finally, note that from our VAR analysis results that, in Italy and Germany, the long-run elasticity between labor market deregulation and TFP is negative and around -0.3%. This implies that labor market reforms may have *adverse* effects on technology progress and productivity. This can happen because a more flexible labor market can reduce the incentive of firms to invest and innovate in order to improve their competitiveness. Obviously, the magnitude of this adverse effects depends on the different productive and institutional structure of the European economies. Therefore, our analysis helps to shed some critical lights on the optimist view that more flexible labor markets and depreciation of the real exchange rates are necessary preconditions to relaunch productivity and techology progress in the long run.

5.1.3 Forecast Error Variance Decomposition.

While the IRFs trace the effects of shocks to one variable on other variables along time, the forecast error variance decomposition (FEVD) technique measures the proportion of forecast error variance in one variable explained by shocks in itself and the other variables at various horizons.

To identify shocks in each of the variables, and the dynamic responses to such shocks, the variance-covariance matrix of the VAR is factorized using the previous Choleski decomposition. The results of the FEVD at various periods, generated by the five-variable of the reduced VAR model, are reported in Tables 1, 2 and 3. Usually, own series shocks explain most of the error variance of each variable. However, the shock will also affect other variables in the system. From our decomposition we get four main results.

First, as expected, the decomposition shows that the percentage of TFP

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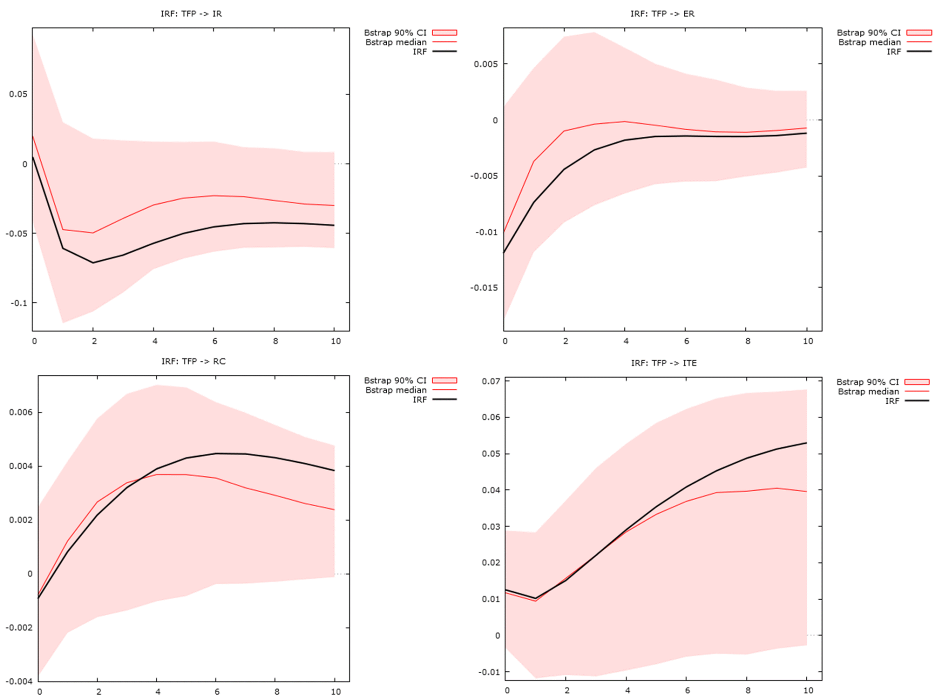

$_5$.pdf

Figure 5: Italy: Responses to a TFP shock.

2

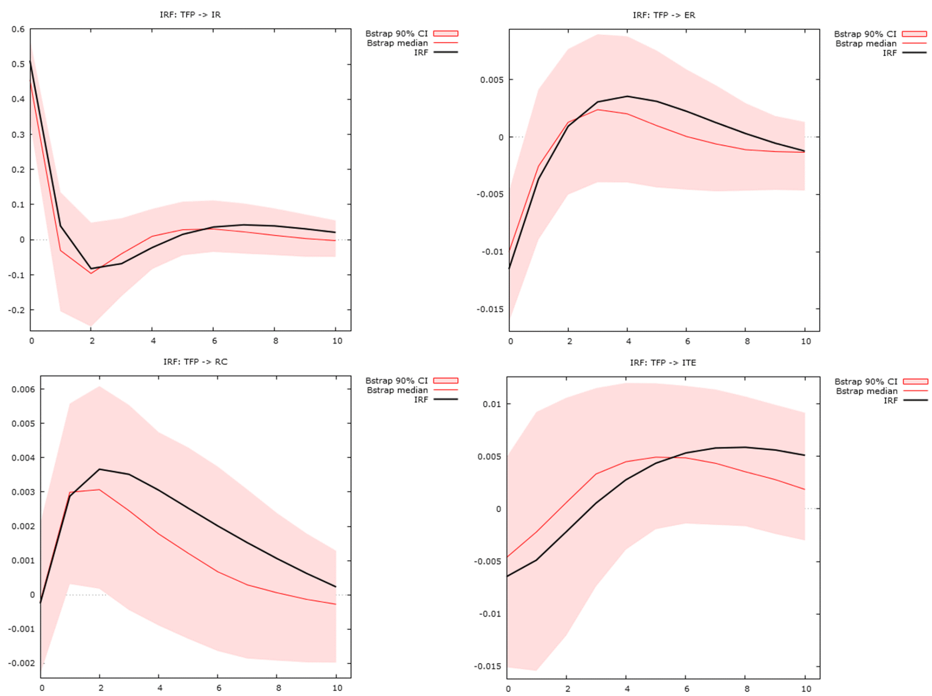

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Figure 6: Germany: Responses to a TFP shock.

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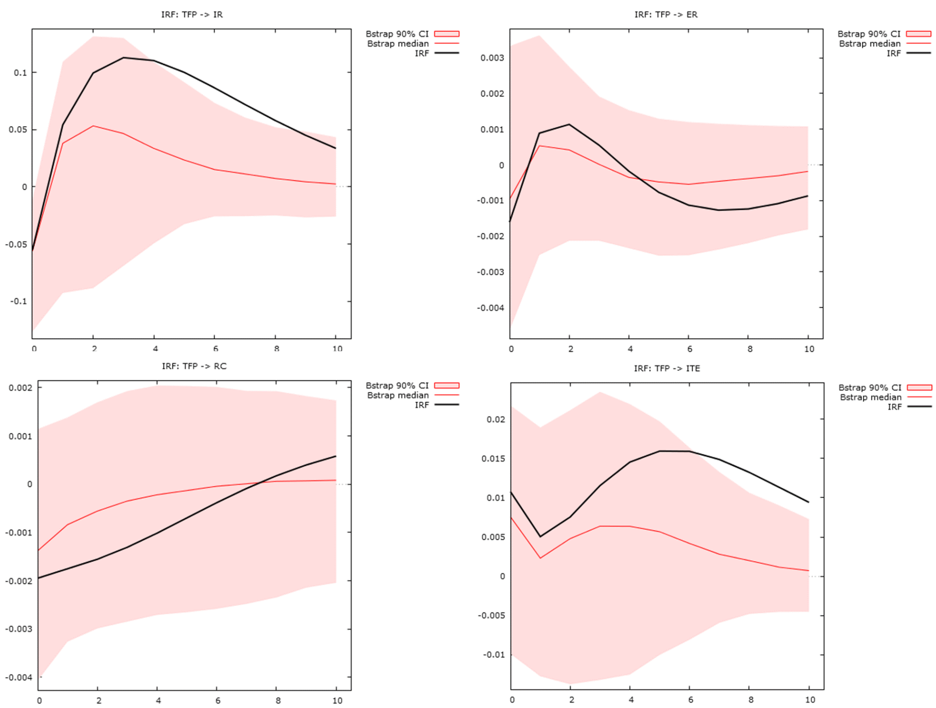

7.pdf

Figure 7: France: Responses to a TFP shock.

variance explained by its own shock is initially high but declines to about 90%, after a10-year horizon, in Germany and 81% in Italy. By contrast, in France, after the initial step, the TFP variance tends to fall converging towards the average value 64% after 10 years. It is worth noting that the proportion of variance attributable to the TFP shocks decreases as the horizon lengthens. This implies that the TFP is highly endogenous, with the remaining variables accounting for the residual volatility in TFP to various degrees.

Second, in France and Italy an important role, in explaining TFP volatility, is played by shocks in ITE (shocks in labor market legislation) which accounts for respectively 18% and 10% of the total TFP variance in the long run. On the contrary, this shocks in labor market have a limited impact in Germany where the total proportion of TFP volatility is steadily below 1%.

Third, the effect of shocks to the interest rate IR on the TFP is quite negligible in Germany (where it explains at most 0.22% of the TFP variance after 10 years) and limited in France (with a contribution of 2.1%). Conversely, it is more consistent in Italy where at the end of the periods the proportion of error variance rises at 4%. With regards to the real wage RC, it accounts for about $0.3 - 0.75\%$ of the TFP variances of France and Germany, and something less in Italy (where the explained variance is near 0.1%) but only in the short-run. Indeed, as time passes the importance of this price shock tends to increase, with a proportion which runs from the 3% in Italy and France to 9% of Germany. For this latter country such a shock largely dominates the others.

Lastly, in France the TFP variance is in part explained by the variations in the real exchange rate ER (12%), while in the remaining two countries this effect is negligible (0.02% in Germany and 1.53% in Italy). Moreover, it is worth noting that the importance of this shock has the tendency to increase over time. Altogether, after 10 years, the shocks have an impact on TFP volatility of about 36% in France, 19% in Italy and 10% in Germany. Obviously, the ordering of the variables can affect the FEVD. However, our results do not significantly change using a different ordering of the variables in the model.

Table 2. **Variance decomposition TFP - Italy**

Period	Stan. Error	TFP	ER	ITE	RC	IR
0	0.01	100	0	0	0	0
5	0.02	92.8	0.21	3.26	2.15	1.55
10	0.03	81.49	1.53	10.07	2.98	3.93

Source: Authors calculation.

Table 3. **Variance decomposition TFP - Germany**

Period	Stan. Error	TFP	ER	ITE	RC	IR
0	0.01	100	0	0	0	0
5	0.02	94.4	0.02	0.41	4.84	0.27
10	0.03	90.9	0.02	0.28	8.53	0.22

Source: Authors calculation.

Table 4. **Variance decomposition TFP - France**

Period	Stan. Error	TFP	ER	ITE	RC	IR
0	0.01	100	0	0	0	0
5	0.01	83.1	3.45	12.13	0.91	0.41
10	0.02	64.3	12.3	18.1	3.16	2.11

Source: Authors calculation.

6 Conclusions

In this paper we study how the asymmetric path of TFP, in three major European countries over the last decades, can be determined by four potential sources. To shape our view, we use a labor market model in open economy with technology progress. Then, we test its predictions by means of a VAR model for the three European countries under investigation, namely Germany, France and Italy over the period 1960-2016.

We get several results.

First, the empirical results confirm that "capital misallocation" and "labor misallocation" can negatively affect TFP in the long run. In other words, TFP has a positive relation with input prices in the long run, while it may be biased along the cycle because of price stickness.

Second, we detect for Germany and Italy a positive long-run relationship between TFP and real exchange rate. This interesting outcome strengthens the *supply-side* view of the relationship between productivity and real exchange rate according to which a "hard" currency can often induce firms (and policy makers) to update technology in order to recover productivity in the long run. Obviously, this behavior strengthens competitiveness and profitability. Therefore, our findings suggest that the divergence in TFP and productivity in the eurozone can be, at most, only partially explained by the "hard" exchange rate policy. Rather, as argued in the analysis, the observed divergences in TFP can be traced back to the "misallocation effects" attributable to the decrease of real interest rate and real wages, together with the raising labor flexibility. These shocks, by widening in the short run the profit margins of firms tended to weaken their willingness to invest and innovate in the long run.

All in all, our findings confirm that four potential sources can explain, over the last decades, the divergence of the major European economies in the eurozone. From our analysis also emerges that the impact of the real exchange rate on TFP is positive for some countries.

As said at the beginning, the present model is stylized and may not capture all of the details of reality. The analysis should be extended to a larger number of countries. Technology progress could be proxied using different variables, as the R&D expenditure or the number of patents. Micro data, for specific sectors and industries, can improve the quality of the empirical investigation. Of course, we aim at extending the present setup in these directions. However, we believe that the present setup can be helpful to reflect critically on the nodes at the core of the productivity slowdown and asimmetries in the eurozone. The aim is to implement renewed policies in order to favor economic growth, convergence and stability in the Euro area.

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