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The Productivity Slowdown Puzzle. Technological and Non-technological Shocks in the Labor Market

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Abstract In this paper we address the question of whether labor supply shifts are the only source of the productivity slowdown that occurred across European countries in the last 15 years. This explanation implies that labor demand shifts are irrelevant. Using a simple dynamic model of the labor market, we show that the poor economic performance of the European countries can only be accounted for by a combination of two shocks: an adverse technological shock to the labor demand and a positive *non*-technological shock to the labor supply resulting from changes in institutions. We use a structural VAR model to estimate the contribution of these two shocks to the dynamics of employment and productivity. Our main conclusion is that technological shocks explain the decrease of the growth rate of productivity but not the increase in employment. The *non*-technological shocks, on the other hand, can capture the increase of employment but not the slowdown of labor productivity. Thus, both shocks are necessary to provide a complete picture of the employment-productivity trade off in Europe during the last 15 years.

Key Words: Productivity slowdown, labor market, SVAR
JEL Classifications: E32, J60, E29

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1. Introduction

In the last 15 years, European countries have recorded the worst economic performance since the end of the Second World War. This disappointing evolution has been the subject of increasing scrutiny over recent years. The main issue has been the simultaneous deterioration of the European countries' productivity and the rise in employment relative to that in the USA. Labor productivity has grown strongly in the USA in recent years while growth rates of continental European countries such as Italy, Spain, France and Germany have slowed markedly.

Table 1 – containing some growth indicators for the USA and the average of European countries (EU15), taken from the Ameco database – shows that since the mid-1990s, in the EU15, labor productivity fell, while employment increased. This dynamics witnessed a reversal of the traditional roles of employment and productivity in contributing to growth: for the first time since the 1960s, the output growth in the EU15 mainly stems from an increasing employment rather than productivity. Yet, this strong recovery of labor utilization was accompanied by a corresponding negative trend, which emerged for productivity. In contrast, in USA productivity increased strongly.

Since the launch of the Lisbon agenda in 2000, about 10 million jobs have been created in the EU15. This strategy has provided a satisfactory answer to the problem of the rising European unemployment of the 1980s, but many countries have seen labor productivity decline over the same period. Thus, after the jobless growth of the 1980s and early 1990s, recent years have witnessed *growthless* job creation.[1] One possible explanation to this phenomenon is that the rise in employment itself has caused the productivity slowdown. A short-run trade-off between employment and productivity may indeed emerge if the rising employment entails a lower capital per worker, and if more workers with relatively low skills are employed.

Most of the recent literature has focused to shocks to labor supply – such as changes in real-wage aspirations and labor market institutions – to explain differences in economic performance among countries. In this perspective, the productivity slowdown in the EU15 is only a short run effect of the increase in the employment rate, with productivity recovery in the long run.

However, in principle, any number of causes can explain the current trade-off between employment and productivity, including a deceleration of the technological progress, a decrease in the ratio of capital stock per worker, an adverse effect of the composition of labor supply due to recent immigration, changes in labor market policies and institutions, variations in the distribution of income with unfavorable consequences on profits and investments, or any combination of these.

We address the question of whether the shift in the labor supply curve is the only fundamental change capturing the negative correlation between the growth rates of productivity and employment. If this explanation is correct then the labor demand curve did not shift in recent times, keeping other features of the production function unchanged. This problem of identification may account for the mixed empirical results found by several authors on the relationship between

[1]European Commission, *EU Economy: 2007 Review - Moving Europe's Productivity Frontier* (p.71).

Table 1. Decomposition of the GDP growth rate

Growth rate	1966–1970	1971–1980	1981–1990	1990–1994	1995–2007
			USA		
GDP	3.4	3.2	3.3	2.3	3.3
Labor (total hours)	1.5	1.6	1.7	0.9	1
Hours worked per worker	−0.9	−0.5	−0.1	−0.2	−0.1
Employment	2.4	2.1	1.8	1	1.2
Labor productivity (hourly)	1.9	1.6	1.5	1.5	2.3
			EU15		
GDP	4.6	2.9	2.4	1.7	2.2
Labor (total hours)	−1	−0.9	0.1	−0.7	0.8
Hours worked per worker	−1.2	−0.7	−0.6	−0.5	−0.4
Employment	0.2	−0.2	0.7	−0.2	1.2
Labor productivity (hourly)	5.6	3.8	2.3	2.4	1.4

productivity and employment. For example, Hansen and Wright (1992), Chirinko (1995) and Christiano *et al.* (2003) find evidence of procyclical employment and productivity to technological improvements in the short run. In turn, Gamber and Joutz (1993) and Galì (1999, 2004), Galì *et al.* (2002) and Francis and Ramey (2003) find evidence of countercyclical employment, and, finally, Christiano *et al.* (2001) and Smets and Wouters (2003) find evidence that requires a variety of stochastic disturbances to capture the evolution of employment and productivity over time.

More recently, Basu *et al.* (2006) made a step forward. They explore the dynamic response of the USA economy to technological shocks, studying the short and long run properties of aggregate output and employment series. In their model, technology improvements *increase* employment in the long run, although they *reduce* employment in the short run. Thus, as they conclude 'after a year or so the response to our estimated technology series more or less matches the predictions of the standard frictionless RBC model. But, the short-run effects do not.'

As we will show below, our empirical findings are almost identical to the patterns reported by Basu *et al.* (2006). Labor productivity is positively correlated with technological shock in the long and short run, while employment responses to technological shock are partly affected by nominal rigidities in the short run, with flexibility prevailing in the long run.

Basically, we focus on the long run properties of the economy. In our model long run movements in productivity and employment are attributed to changes in technology and institutions. We refer to these changes as *technological* and *non-technological shocks*. Our aim is to quantify the role of these shocks in determining growth by making minimal and plausible assumptions. Other sources of fluctuation, such as aggregate demand, are accommodated in the model, but they affect only the short run evolution of the economy.

Our analysis has three main results. We show that sources of technological and non-technological shocks match the short and long run characteristics of employment and productivity. Next, our labor market model shows that a combination of technological and non-technological shocks can explain the observed negative correlation between the growth rate of employment and productivity in the short run. Nonetheless, in the long run, technology improvements are expansionary, with employment and (especially) productivity rising over time. Finally, we explain how a structural vector autoregressive (SVAR) model can exploit the different responses of productivity and employment to each type of shock. We derive measures on the relative magnitude of the responses of variables to the shocks and their changes over time. In the long run, labor productivity responds positively to technological shock, while non-technological shock induces only short run movements in productivity. On the other hand, the responses of employment to technological shock are weak and unable to explain the increase in employment. Thus, both shocks are necessary to provide a complete picture of the trade-off between employment and productivity in the European countries during the last 15 years.

The paper is organized as follows. After a brief review of the literature, section 3 presents the main basic facts characterizing the evolution of the European economy in the last 15 years. We focus on three specific issues. How does the EU15 compare with the USA in terms of economy-wide productivity trends, and how big is the role of labor participation, capital accumulation and technological progress in the EU15 economy? Is labor participation or labor productivity responsible for the EU15's decline during the last ten years? Is the decline in productivity growth structural in nature or is it cyclical? With an eye to the evolution of these variables, the dynamic properties of our model will be discussed in section 4. In the fifth section, we will identify the components of employment and productivity associated with alternative shocks. Section 6 concludes.

2. Related Literature

There are innumerable papers dealing with the European economic performance. We can divide these contributions into three main groups.

A lot of effort has been devoted to studying the causes of the increasing European unemployment during the previous two decades. Many papers focus on the upward shifts of the labor supply curve, emphasizing the effects of institutional changes on the level of (un)employment. We can label this explanation as the labor supply-side approach (Layard *et al*., 1991; Nickell & Layard, 1999; Belot & Van Ours, 2000, 2001; Garibaldi & Mauro, 2002; Nickell, 2003). This strand of research is well represented by Nickell *et al*. (2005). Their empirical evidence remarks that in the last 40 years the evolution of unemployment in Europe is well explained by changes in labor market institutions.

Other contributions by Blanchard (1997), Caballero and Hammour (1998), Bertola *et al*. (2002) have studied the interactions between shocks and institutions. The central idea here is that the rigidity in labor market institutions amplifies the initial shock (interest rate, aggregate demand, input price) with a negative and persistent effect on the equilibrium level of unemployment. The influential paper by Blanchard and Wolfers (2000) is perhaps the most notable example. They show that while adverse shocks can explain much of the rise in unemployment, only the interactions between shocks and institutions can capture the heterogeneity of unemployment across European countries from the 1960s to the beginning of the 1990s. Finally, a recent contribution by Gordon and Drew-Becker (2008) updates this explanation on the trade-off between employment growth and productivity growth. They examine changes in policy/institutional labor market variables over the time period between 1978 and 2003 and find that the turnaround from making labor more expensive to less expensive occurred with a different time path for each variable. They attribute the policy turnaround in the policy-institutional variables to two major sets of impetus to change the EU policy framework – the 1994 OECD Jobs Strategy and the 2000 Lisbon Agenda.

A more recent strand of research focuses on the labor productivity slowdown in European countries in the last decade. Much of this research is based on growth accounting. A large number of empirical papers study the deterioration of the technological progress and its effect on labor productivity. An adverse technological shock can explain the deceleration of the productivity growth rate in the European economy (Denis & Roger, 2004; Estevao, 2004; O'Mahony & van Ark, 2003; Timmer & van Ark, 2005; European Commission, 2004, 2007). A revealing quantitative analysis of this phenomenon is presented in Inklaar *et al.* (2005). They analyze at industry-level the sources of growth in four European countries: France, Germany, the Netherlands and the UK. Labor productivity growth is decomposed into industry-level contributions of labor quality, ICT and non-ICT capital deepening and technological progress (TFP). Their main upshot is that both the slowdown in TFP and the widespread deceleration in non-ICT capital deepening have led to a European productivity slowdown. This is linked to wage moderation in the 1990s.

However, all these papers do not provide an explicit theoretical model to study this relationship. Thus, since the exact nature of the shocks, the relative importance of them, and the mechanisms through which the shocks interact remain largely to be established, we combine both types of shocks. In this perspective, the present study can be seen as an update of Blanchard (1997) who made the first attempt to explain the rising of unemployment in Europe using a labor market model with shifts in both labor demand and supply.

3. Four Stylized Facts

Before going any further, it is worth looking at the next four figures. They show that, from the beginning of 1990s, European economies were characterized by four seemingly conflicting stylized facts. (All the data shown in this section are from the Ameco database).

The first is well known: the EU15 economies have experienced important changes in labor market institutions over the course of the 1990s with an increase in the employment rate (see Figure 1).

However, during the same period, the strong recovery in labor utilization was accompanied by a correspondingly negative trend in labor productivity. Figure 2 illustrates that EU15 labor productivity growth rates have been declining from the mid-1990s by 1 percentage point while the USA's has been accelerating by a roughly similar amount.

The other two basic facts are less well known but equally important. First, the post-1995 deterioration in labor productivity is associated with an increase in the

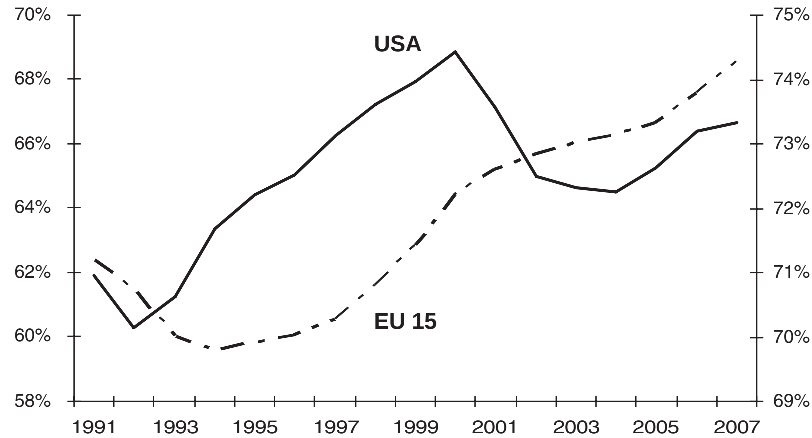

Figure 1. Employment rate. EU15 (left scale), USA (right scale).

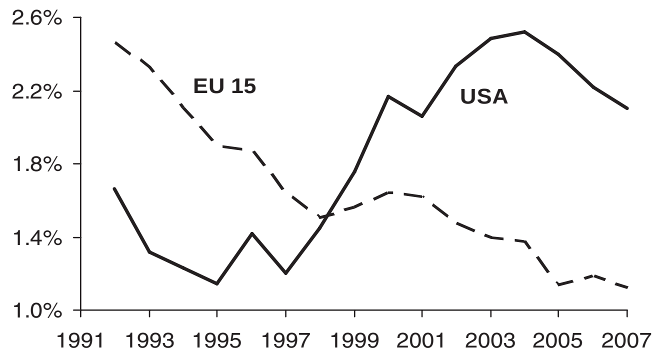

Figure 2. Labor productivity trends (MA(5), growth rate). Ratio between real GDP and total employment.

profit share. Nowadays, in the EU15 this is higher than in the USA. In contrast, profit share in USA remained quite stable (Figure 3).

While it can be questioned whether this change in income distribution can be useful to sustain new investment and growth, what is more puzzling is the significant fall in the EU15 capital-deepening growth during the same ten years (Figure 4): during the period 1995–2007, in the EU15 and Italy, the capital-deepening growth rate decreased, signaling that firms switched to more labor-intensive forms of production. As a result, a growing gap in terms of labor productivity, technology and capital deepening emerged over the second half of the 1990s in favor of the USA.

To strengthen the relevance of the four previous stylized facts it is helpful to analyze the main European economies separately since each country has different characters in terms of labor market organization and productivity. We focus on five major European countries (France, Germany, Italy, Spain and United Kingdom) in comparison with the USA for the period from 1971 to 2007. Table 2 provides

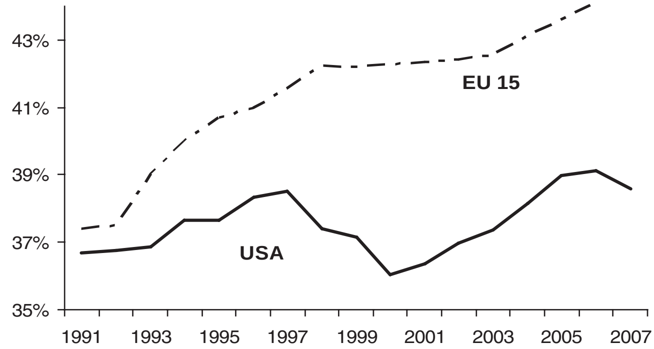

Figure 3. Profit share. Ratio between operating profit and national income.

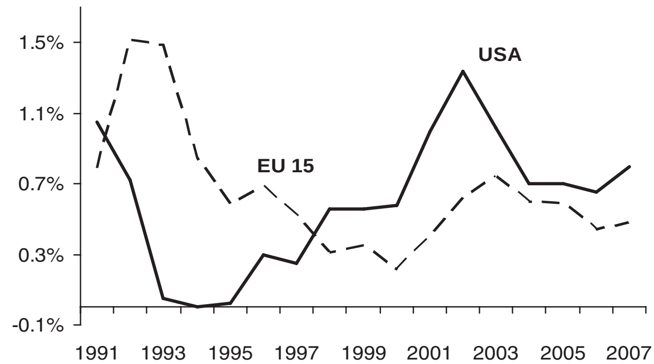

Figure 4. Capital deepening (growth rate).

the breakdown of the GDP growth rate into the contribution of employment, productivity, technological progress (TFP) and capital deepening. We use standard growth accounting to decompose the GDP growth rate.

These data confirm our previous remarks. For the USA, the average GDP growth rates remained largely stable throughout the entire period, with an acceleration of labor productivity, and a deceleration of the employment rate in the last 15 years. This evolution is accompanied by an increase in both average growth rate of TFP and capital deepening. In turn, in Europe, four basic facts make the point from the beginning of the 1990s. European countries have experienced an increase in labor utilization after two decades of rising unemployment. During the same period, the recovery in labor utilization was accompanied by a corresponding negative trend in the growth rate of productivity. There is a strong decline in TFP growth rate as well. The growth rate of capital deepening has decreased, signaling that firms switched to more labor-intensive forms of production.

The comparative dynamics of these historical data provides a first outcome. In European countries and in the USA, the last 15 years witnessed a reversal of the traditional roles of employment and productivity in contributing to growth. In Europe, the recovery of labor utilization was accompanied by a corresponding

Table 2. Breakdown of GDP growth rate in its components. Total economy

Growth rate	1971–1980	1981–1994	1995–2007	Growth rate	1971–1980	1981–1994	1995–2007
USA				**Italy**			
GDP	3.2	2.9	3.3	GDP	3.7	2.0	1.4
Labour	1.6	1.5	1.0	Labour	−0.3	−0.2	0.4
Productivity:	1.6	1.4	2.3	Productivity:	4.0	2.2	1.0
TFP	1.2	1.1	1.6	TFP	2.6	1.2	0.3
Capital deepening	0.4	0.3	0.7	Capital deepening	1.4	1.0	0.7
Growth rate	**1971–1980**	**1981–1994**	**1995–2007**	**Growth rate**	**1971–1980**	**1981–1994**	**1995–2007**
France				**Spain**			
GDP	3.3	2.1	2.0	GDP	3.5	2.4	3.5
Labour	−0.4	−0.6	0.4	Labour	−1.2	−0.2	2.9
Productivity:	3.7	2.7	1.8	Productivity:	4.7	2.6	0.6
TFP	2.1	1.5	1.0	TFP	2.6	1.4	0.2
Capital deepening	1.6	1.2	0.8	Capital deepening	2.0	1.2	0.4
Growth rate	**1971–1980**	**1991–1994***	**1995–2007**	**Growth rate**	**1971–1980**	**1981–1994**	**1995–2007**
Germany				**United Kingdom**			
GDP	3.3**	1.3	1.4	GDP	1.9	2.2	2.7
Labour	–	−1.0	−0.3	Labour	−0.7	0.0	1.2
Productivity:	–	2.3	1.7	Productivity:	2.6	2.2	1.5
TFP	–	1.0	1.0	TFP	1.7	1.7	1.2
Capital deepening	–	1.3	0.7	Capital deepening	0.9	0.5	0.3

Notes: Employment and productivity are expressed in hours. ** Germany before unification. * After reunification. Average growth rates. Ameco database

negative trend of labor productivity. This performance marks a serious downgrading relative to the early 1990s when annual labor productivity growth was about 2.4%, compared with 1.4% for the USA. Since then, there has been a reversal in fortunes, with the European countries' labor productivity growth rate declining, on average, by roughly 1%, and with the USA accelerating by a similar amount. From a growth accounting perspective, the 1 percentage point decline in European labor productivity emanates from two sources. About 40% can be attributed to a reduction in the capital-deepening contribution. The remaining part emanates from the deterioration of TFP. Nonetheless, during the same period, the capital share in the European economy has increased.

4. A Simple Graphical Analysis

Is the slowdown in labor productivity growth rate likely to be a permanent or a temporary phenomenon? To answer this question, it is helpful to look at the graphs in Figure 5, showing the scatter between the growth rates of labor productivity and employment in European countries from 1990 to 2007.

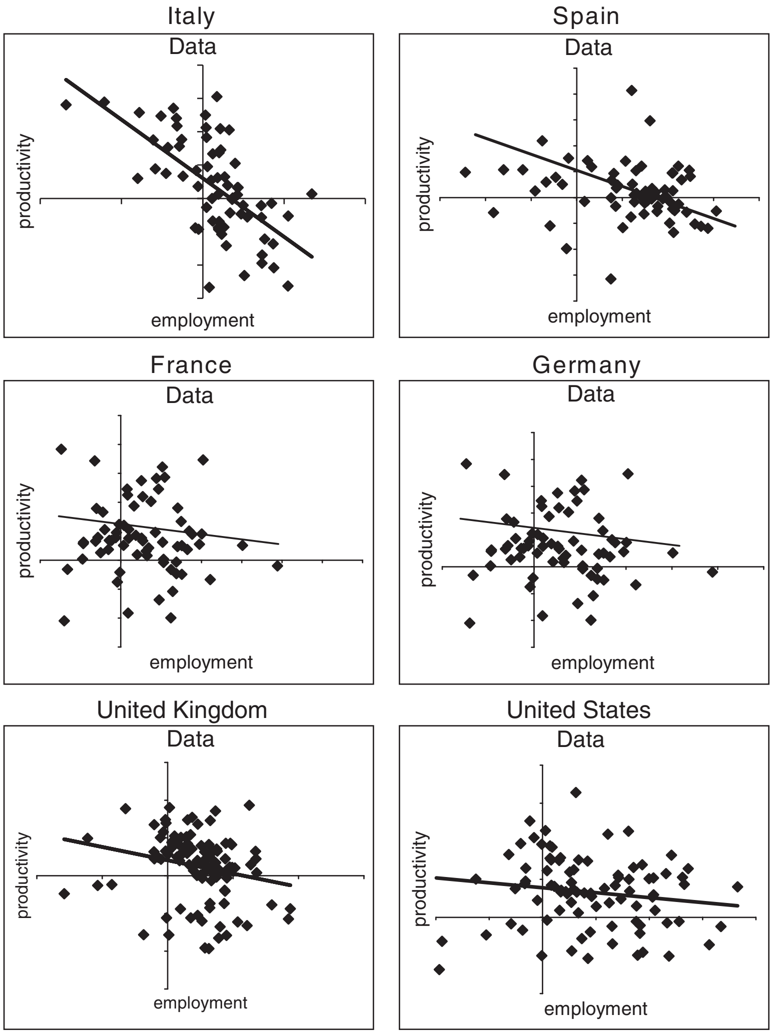

Figure 5. Scatter between labor productivity and employment growth rates. Historical data. 1990–2007.
Notes: Quarterly data.

This comparison shows the existence of a negative (and sometimes near zero) correlation between these two variables. The regression line has a negative slope, and for Italy, Spain, the UK and the USA it is a statistically significant linear relationship.[2,3] Looking at these data we could be tempted, at first sight, to interpret the negative correlation as a movement along the labor demand curve, or as a shift

[2]Data are from Eurostat database, OECD database and Federal Reserve of St. Louis database. Germany 1993–2007.
[3]See Hansen and Wright (1992) for a discussion of the employment-productivity puzzle and Galì (1999) for the anomalies regarding the labor market predictions of RBC models.

in labor supply curve. This is what we have called the labor supply-side approach. This interpretation explains the recent productivity slowdown as a response of the economy to a positive labor supply shock. The shock to labor supply could be the result of labor market reforms and wage moderation. It could also reflect an increasing immigration of unskilled workers with a lower reservation wage. These changes could have contributed to an increase in labor force participation. Under this interpretation, a slower wage growth could have led to a temporary decline in the capital-labor ratio with a deceleration in labor productivity growth. Once full employment is attained, wage and productivity growth could accelerate again and the economy could return to a higher productivity level. The recent decline in productivity growth could be regarded as a temporary phenomenon.

However, how much does the decrease in productivity growth reflect an increase in employment? How much might it reflect a decrease of both technological progress and capital deepening? Can we be sure *a priori* that the labor demand curve did not shift in recent times, so that the deceleration in labor productivity is only a short-run phenomenon?

Answering this is obviously hard. Nonetheless, we find the following exercise useful. If we are willing to assume that multiple shocks affect the equilibrium in the labor market, then we can construct an explanation of the productivity slowdown that depends on both the shifts of supply and demand of labor. Our explanation looks at a possible interaction between technological and non-technological shocks. We call technological shocks the change in the growth rate of TFP, and non-technological shocks the institutional changes in labor market, with their effects on regulation and wage.

We offer the following explanation of the four basic facts. Firms reacted to deregulation in labor market (non-technological shocks) reducing capital deepening and switching towards more labor-intensive technology. The initial effect has been to raise capital shares and to reduce the growth rate of productivity. However, since mid 1990s, the labor market has been characterized by an adverse shift in labor demand. One explanation of this shift is the deceleration in the growth rate of technological progress, as shown by the evolution of TFP (technological shock). Moving away from skilled labor, firms led to a decrease in the growth rate of technological progress with a further negative impact on productivity.

We employ a labor market model with shifts in labor supply and demand to explore this interpretation. We make two main assumptions. First, as in Solow's model, we assume that the rate of technological progress affects labor productivity and capital intensity in the steady state. Secondly, we assume that the equilibrium in the labor market is affected by institutions and by changes in institutions.

The result of these assumptions is presented in Figure 6. It illustrates the interaction between supply and demand shocks in labor market.[4] Labor supply curve

[4]Speaking of adverse technological shocks is just for the sake of exposition. Indeed, we can formally represent the labor market in terms of growth rates. Let the production function be $Y = AN^{1-\alpha}$, with A representing the technological progress, and $1 - \alpha$ the income share of labor. The marginal productivity is $A(1-\alpha)N^{-\alpha}$. In terms of growth rates, this latter expression becomes $\dot{A}/A - \alpha\dot{N}/N$. Hence, the labor demand curve has a negative slope, and it shifts downwards to the left

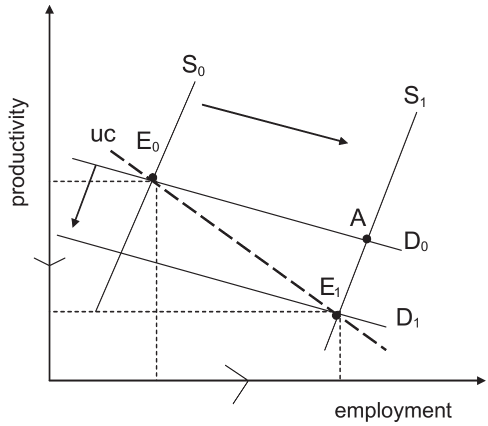

Figure 6. The interaction between technological and non-technological shocks.

is affected by non-technological shocks. Thus, the effect of deregulation is to shift labor supply down to the right from S_0 to S_1, along the demand curve. In the short run, labor productivity decreases as well as unemployment, moving towards point A. However, this point cannot be a long-run equilibrium. Indeed, technological shocks affect the position of the labor demand curve. Let us consider an adverse shock in technological progress. Its effect is to decrease the (growth rate of) labor productivity, shifting permanently the labor demand curve down to the left from D_0 to D_1. The long-run equilibrium shifts from E_0 to E_1, where employment is higher and labor productivity is permanently reduced. The *uc* line in Figure 6 provides a theoretical account of the empirical line of the previous scatters: the two shifts originating in technological and non-technological shocks explain the negative unconditional correlation.

The main implication of this scenario is that technological progress permanently affects the steady state, affecting both the growth rates of labor productivity and employment. Hence, we have a prediction on the sign of the *conditional* correlations. For technological shocks, the conditional correlation between the growth rates of employment and productivity must be positive: given labor supply and institutions, it reflects the shift in labor demand curve caused by technological changes. For non-technological shock, the conditional correlation must be negative: given labor demand and technological progress, it reflects the shift in labor supply curve caused by institutional changes.

We build up a theoretical labor market model in which employment and productivity react to each shock. We will then identify and estimate the components of the productivity and employment associated with the two alternative shocks using a SVAR model.

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whenever the technological progress decelerates. Similarly, the labor supply curve can be expressed as $w = \theta N$, where θ is a black box representing the institutional factors in the labor market. In terms of rates of growth it can be written as $\dot{\theta}/\theta + \dot{N}/N$. As a consequence, whenever labor flexibility increases – which means a reduction in $\dot{\theta}/\theta$ – the supply curve shifts downwards to the left, increasing the growth rate of employment.

5. The Model

In this section, we formalize the previous intuition. This model is a version of Blanchard (1997). The main difference is that in this version the technological shock *modifies* permanently the steady state of labor market.

Let us assume that every firm uses one unit of capital. When the single firm chooses the amount of labor to hire, it also decides the corresponding labor to capital ratio. For the single firm, the optimal labor demand is given by the solution of the following Bellman equation:

$$\rho v(n) = \max_{\dot{n}} \left[An^{1-\alpha} - wn - \frac{c}{2}(\dot{n})^2 + \frac{\mathrm{d}}{\mathrm{d}t} v(n) \right] \tag{1}$$

In this equation, $v(n)$ is the value of the firm expressed as a function of the labor-capital ratio, n. As usual, the left-hand side of this equation is the cost of financing the firm, since ρ is the user cost of capital. The right-hand side is the market value of the firm given by the operating profits plus the capital gain. A is the technological progress. To get an analytical solution we assume that the operating profit is the difference between the real value of output $y = An^{1-\alpha}$ minus both the real cost of labor wn, and the quadratic costs $\frac{c}{2}(\dot{n})^2$ that the firm has to bear to adjust (hiring and firing) labor. The first-order and the envelope conditions are:

$$c\dot{n} = v_n$$
$$\rho v_n = A(1-\alpha)\, n^{-\alpha} - w + v_{nn}(n)\, \dot{n}$$

and putting $v_n = q$, the previous conditions become:

$$\begin{aligned} c\dot{n} &= q \\ \rho q &= A(1-\alpha)\, n^{-\alpha} - w + \dot{q} \end{aligned} \tag{2}$$

The first equation says that the firm will increase employment up to the point where its marginal value q is equal to the adjustment cost, $c\dot{n}$. Then, from the second equation we get that, along the optimal path the marginal cost of financing the firm, ρq must be equal to the marginal value of the firm. Substituting these two expressions in the Bellman equation (1) we obtain:

$$v(n) = \frac{1}{\rho} \left\{ An^{1-\alpha} - wn + \frac{q^2}{2c} \right\} \tag{3}$$

which provides the value of the firm.[5]

[5]The quadratic term represents the rents accruing to the firm and deriving from the adjustment cost technology. Along the optimal path, a marginal increase of employment increases the value of the firm by $v_n\dot{n} = q \cdot q/c = q^2/c$. At the same time, marginal adjustment costs increase by $(c/2) \cdot (\dot{n})^2 = q^2/2c$. Thus, the value of the firm increases by $q^2/2c$.

The firm must decide whether it is convenient to keep producing or exit the market. It compares its current value $v(n)$ to the cost of one unit of capital. This cost depends on the market demand for capital. Hence, the unit cost of capital p_k can be written as the sum of its direct cost normalized to 1 plus an adjustment cost, which depends on the aggregate investment $\dot{K}$:

$$p_k = 1 + h\dot{K} \tag{4}$$

Free entry implies that:

$$v(n) = 1 + h\dot{K} \tag{5}$$

which defines the investment demand:

$$\dot{K} = \frac{1}{h}[v(n) - 1] \tag{6}$$

Now, let us focus on the labor market equations.

The aggregate labor demand is simply the sum of the individual demands, that is:

$$N = nK \tag{7}$$

For the labor supply we assume that it is a linear increasing function of real wage. At market level, if the labor force is normalized to 1, we can write:

$$w = \theta N$$

As we said above, θ is a black box representing the labor market institutions, with its variations giving account of institutional changes. The labor market equilibrium is then given by:

$$w = \theta nK \tag{8}$$

Finally, by assumption, the user cost of capital ρ is an exogenous variable defined by international competition in capital markets. With a Cobb-Douglas production function this assumption implies that the real wage is fixed in the long run to the level w^*.

The following system of differential equations characterizes the economy:

$$\begin{cases} \dot{n} = \dfrac{1}{c}q \\ \dot{q} = \rho q - [A(1-\alpha)\, n^{-\alpha} - w] \\ \dot{K} = \dfrac{1}{h}(v - 1) \end{cases} \tag{9}$$

In order to study the properties of this system, we begin determining the *steady state* of the economy. Since we have that, in equilibrium, $\dot{q} = q = 0$, the steady state real wage is:

$$w^* = A(1-\alpha)\, n^{*-\alpha} \tag{10}$$

that is, w^* is equal to the marginal product of capital. Then, since in steady state the marginal product of capital must be equal to the user cost (which is what the

Bellman equation states), we have:

$$\rho = y - wn = \alpha A n^{1-\alpha}$$

so that the steady state labor-capital ratio is:

$$n^* = \left(\frac{\rho}{aA}\right)^{\frac{1}{1-\alpha}} \tag{11}$$

It follows that in steady state the real wage is:

$$w^* = A^{\frac{1}{1-\alpha}}(1-\alpha)\left(\frac{\rho}{\alpha}\right)^{\frac{-\alpha}{1-\alpha}} \tag{12}$$

Substituting these latter values in the labor supply equation we get the steady state values of both employment and capital stock at market level:

$$K^* = \frac{1}{\theta}A^{\frac{2}{1-\alpha}}(1-\alpha)\left(\frac{\rho}{\alpha}\right)^{\frac{-(1+\alpha)}{1-\alpha}}$$
$$N^* = \frac{1}{\theta}A^{\frac{1}{1-\alpha}}(1-\alpha)\left(\frac{\rho}{\alpha}\right)^{\frac{-\alpha}{1-\alpha}}$$

We use these two solutions to linearize the system (9) in the neighborhood of the steady state. It can be shown that the system has two state variables (K and N) and one jump variable (q) (a note on the stability analysis is available upon request from the authors). This means that its dynamics is characterized by a stable saddle path.

5.1 *Non-technological Shock*

Suppose that the system is initially in steady state. Then, given employment, a non-technological shock reduces the value of θ. This variation decreases the slope of labor supply and the corresponding wage. At a given level of capital stock, the lower wage increases labor demand, increasing the labor-capital ratio. These effects are shown in Figure 7 where initially equilibrium shifts from E to A.

In the long run, however, the decrease of wage increases the firm's value, making it attractive to enter the market. As a result, both capital and employment increase and the labor demand curve shifts to the right, moving the economy towards the new steady state. In E' the level of employment has increased and the labor productivity has returned to its initial level. Note that in the long run the non-technological shock does not change the labor-capital ratio, although it does increase the use of both the inputs.

The dynamics of the system are illustrated in Figure 8, where, on the horizontal axis, there is time expressed in years. The parameters values are: $\rho = 0.15, \alpha = 0.3, h = 10, c = 4, A = 0.5$. These values give an initial labor-capital ratio equal to $n_0 = 1$ and a wage $w_0 = 0.35$. Given the initial value of $\theta, \theta_0 = 0.385$, we get the capital stock, $K_0 = \frac{w_0}{\theta_0 n_0} = 0.909$, and the employment level, $N_0 = n_0 K_0 = 0.909$.

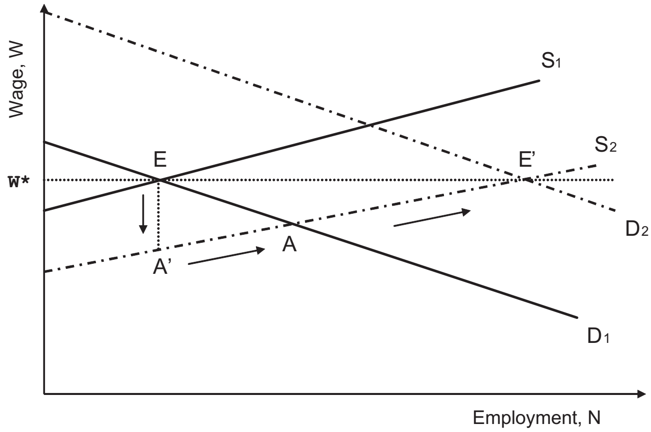

Figure 7. The effect of a greater labor flexibility.

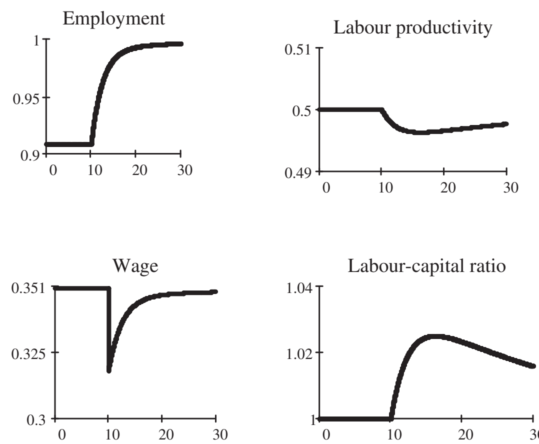

Figure 8. The dynamic effects of a greater labor flexibility.

We then suppose a *reduction* of θ (a positive non-technological shock) such that its value is reduced to $\theta_1 = 0.35$. For the sake of clarity, we assume a shock of 10% of the initial value, so that $\frac{\Delta\theta}{\theta} = -0.1$. The shock arrives after 10 years. Therefore, the simulation implies a lag of the adjustment path of about 20 years.

5.2 *Technological Shock*

Now, let us focus on adverse technological shocks, that is a decrease in the value of A. In our model, only technological shocks have a permanent effect on labor productivity. The impact of this shock is shown in Figure 9 where the labor demand curve shifts down to the left, affecting permanently the steady state (from E to E').

The slowdown of the technological progress has an initial effect on profit rate, wage and labor-capital ratio. Indeed, the reduction in productivity leads the firm

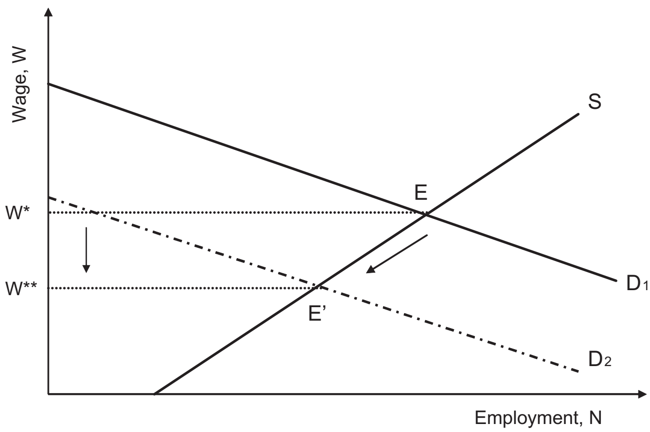

Figure 9. The effect of slowdown in technological progress.

to invest less in the long run, modifying the steady state: given the user cost ρ, a lower productivity can only be offset by a lower wage in the long run. Eventually, this change leads to an increase of the labor-capital ratio.

Note, however, that the technological shock permanently reduces employment in the long run. This outcome conflicts with one of the stylized facts seen above, i.e. the increase of labor utilization during the 1990s. The slowdown of technological progress is thus a potential, even if incomplete, explanation of the European economic dynamics in the last 15 years.

The adjustment paths of the system are described in Figure 10. The parameters' values used are: $\rho = 0.15, \alpha = 0.3, h = 10, c = 4, \theta = 0.35$. The initial value of A is $A_0 = 0.5$; we then have an adverse shock to A such that the new level is

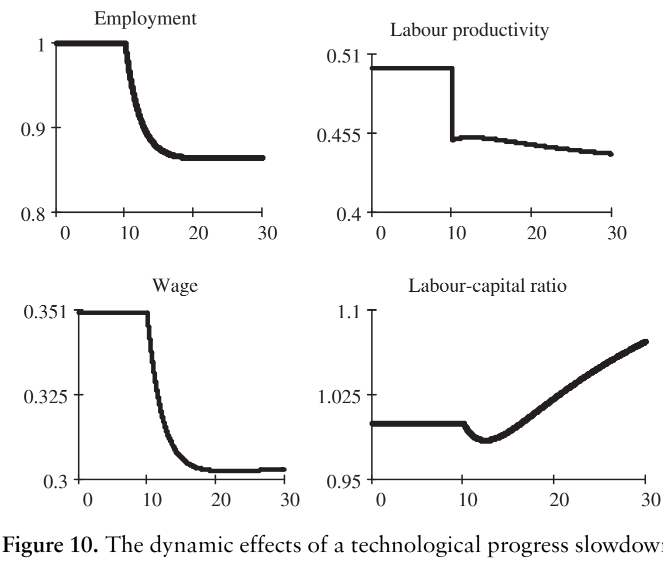

Figure 10. The dynamic effects of a technological progress slowdown.

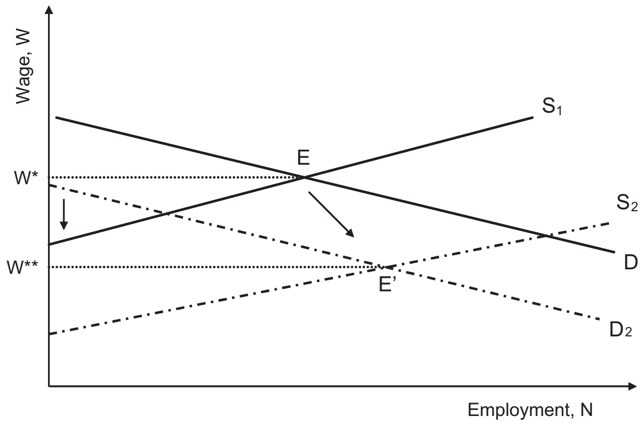

Figure 11. The interaction between technological and non-technological shocks.

$A_1 = 0.45$. Notice that also in this case the size of the shock is equal to 10% of the initial value and the time necessary for the adjustment is roughly the same.

5.3 *Interaction between Shocks*

In this simulation we analyze the interaction between shocks. We study the combined effect of a decrease of θ and A. Figure 11 shows that, in this scenario, the steady state shifts from E to E'.

Comparing the two steady state equilibria, we note that two effects arise: employment increases while labor productivity decreases. The rise of employment is originated in the deregulation. On the other hand, the reduction of both wage and productivity depends on the slowdown of the technological progress. Since

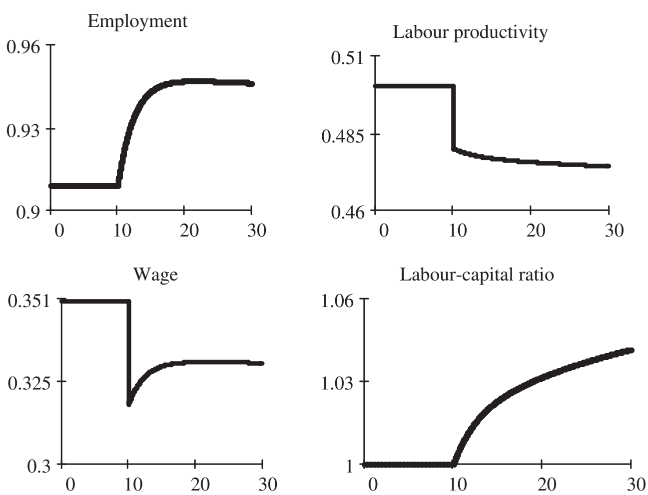

Figure 12. The dynamic effects of the interaction of technological and non-technological shocks.

the user cost ρ is exogenously given, the lower productivity of labor must be offset by a decrease in capital accumulation to increase marginal productivity of capital. This implies an increase of the labor-capital ratio in the long run.

As before, the dynamics of the system is described in Figure 12. The parameters' values are: $\rho = 0.15, \alpha = 0.3$, $h = 10, c = 4, \theta = 0.385, A = 0.5$. Then, both A and θ are reduced to $\theta_1 = 0.35$ and $A_1 = 0.48$ to simulate the combined effect of the two shocks.

In summary, two lessons can be drawn from all these simulations. First, technological shocks can potentially explain the slowdown in labor productivity since the early 1990s. Secondly, we need two separate shocks to capture the joint behavior of employment and productivity. Technological shocks, permanently shifting the labor demand curve down to the left, can capture the adverse evolution of productivity; non-technological shocks, shifting labor supply curve down to the right, can capture the increase in the level of employment.

6. The Structural VAR

The previous model provides the identifying restrictions for the structural VAR. Note that these restrictions allow permanent effects of technological shock on both productivity and employment. Following Galì (1999) we do not restrict technological shocks *not* to have a permanent effect on employment. We assume that only a combination of technological and non-technological shocks can capture the basic facts. Further, in the empirical analysis, we add the aggregate demand to capture the short run component of productivity and employment.[6]

The data used to estimate the SVAR are total employment in full-time equivalent for Italy, France and Spain; total employment for UK; and civilian employment for the USA. Then, we employ real GNP to calculate labor productivity, and real aggregate demand. Data are quarterly. The period goes from 1975q1 to 2006q4.[7] We interpret the observed variation (Δ) in (log) productivity (p), (log) employment (l) and (log) demand (d) as originating from three types of shocks, whose impact is propagated over time. Formally:

$$\begin{bmatrix} \Delta p_t \\ \Delta l_t \\ \Delta d_t \end{bmatrix} = \begin{bmatrix} C_{11}(L) & C_{12}(L) & C_{13}(L) \\ C_{21}(L) & C_{22}(L) & C_{23}(L) \\ C_{31}(L) & C_{32}(L) & C_{33}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_p \\ \varepsilon_l \\ \varepsilon_d \end{bmatrix} = C(L)\varepsilon_t$$

In the matrix $C(L)$, we find the polynomials $C_{ij}(L)$ with individual coefficients denoted by $c_{ij}(k)$. $\varepsilon_p, \varepsilon_l$ and ε_d represent the structural shocks on labor demand, labor supply and aggregate demand. We assume the following long-run

[6] As in Blanchard and Quah (1989), we impose that the aggregate demand shock has no long run impact on productivity and employment. This same assumption is used by Gamber and Joutz (1993) to identify the aggregate demand component of real output and productivity.

[7] The database employed in the econometric analysis is obtained from Eurostat, OECD and the Federal Reserve of St. Louis.

restrictions:

(1) technological shocks have a long run impact on the log of labor productivity, employment and aggregate demand;
(2) non-technological shocks have long run effects on the log of employment and aggregate demand, but they do *not* affect labor productivity;
(3) aggregate demand shocks have only short run impacts on the growth rate of employment and productivity. Given these identifying restrictions, the matrix of the long run multipliers $C(1)$ is:

$$C(1) = \begin{bmatrix} C_{11}(1) & 0 & 0 \\ C_{21}(1) & C_{22}(1) & 0 \\ C_{31}(1) & C_{32}(1) & C_{33}(1) \end{bmatrix}$$

Assuming the shocks are ordered as technological, non-technological and aggregate demand, the above restrictions say that the secular component in labor productivity originates in the technological shocks, and the coefficient $C_{11}(1)$ identifies the long run multiplier of this shock. In turn, the zeros in the matrix imply that both employment and aggregate demand shocks do not affect the log of productivity in the long run (however, they may well have short and medium run effects on it), but that the secular component of the log of employment depends on both technological and non-technological shocks.[8]

The moving-average specification is based on the assumption that the growth rates of variables are stationary. This assumption is motivated by the standard Dickey–Fuller tests and Phillips–Perron tests, which reject the null of unit root when applied to the first differences of log. Two different specifications of the variables in VAR are run to test the robustness of the result. In the first case (specification A) we do not remove means and trends. In the second case, we remove a mean growth shift for employment and aggregate demand after 1992 and we detrend the employment rate. [9] Since the results for the two specifications are similar, we present below only the results for specification A.

Table 3 reports estimates of both unconditional and conditional correlations between the growth rates of employment and productivity, over the period 1975–2006.[10] The unconditional correlation is reported in the first column. As we said above, this correlation is negative in all countries, and, in some case, near zero.

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[8]The restriction $\sum_{k=0}^{\infty}(k) = C_{ij}(1) = 0$ implies that a specific structural shock has no effect on the level of variables in the long-run.

[9]The VARs contain from four to eight lags depending on the specification of the dynamic model. They also include two dummies allowing for the change in the rate of growth of employment and output in 1974 and 1993 for France and the UK, and in 1975 and 1993 for Italy and Spain. The dummies are chosen to coincide with the first OPEC oil shock and with the recession of the European economy of the years 1993–1994. The impulse response functions are similar across alternative treatments of lags, breaks and time trends.

[10]The significance of the correlation index is obtained applying the formula $t = \frac{r}{\sqrt{(1-r^2)/(n-2)}}$, where t is the Student's t, r is the correlation and n the size of the sample. The t value is distributed approximately with $n - 2$ degrees of freedom. Application of this formula to any particular observed sample value of r will test the null hypothesis that the observed value comes from a population in which $r = 0$.

Table 3. Correlation estimates for the European countries and USA. Total economy

	Unconditional	Conditional	
		Technology	Non-technology
Italy	−0.40** (4.84)	0.25** (2.74)	−0.70** (10.4)
Spain	−0.27** (3.11)	0.11* (1.18)	−0.25** (2.74)
France	−0.08 (0.89)	0.56** (7.12)	−0.41** (4.77)
United Kingdom	−0.21** (2.41)	0.22** (2.28)	−0.42** (4.92)
United States	−0.18** (2.03)	0.57** (7.37)	−0.68** (9.85)
Germany	−0.10 (1.12)	–	–

Notes: Growth rates. Quarterly data for the period 1975q1–2006q4. *t* values are in parentheses (125 degrees of freedom). Significance is indicated by one asterisk (10% level) or two asterisks (5% level).

However, the SVAR analysis allows us to disentangle the intricate effects of the different shocks in generating the correlation. Our benchmark estimates of *conditional* correlations are reported in the second and third columns. They are consistent with our theoretical model of labor market. We get a *positive* correlation between the growth rates of productivity and employment conditional on technological shocks; and a *negative* conditional correlation to non-technological shocks.[11] Thus, the historical correlation provided by the data can be reconciled with shifts in both the demand and the supply curve in the labor market: productivity responds positively to technological shocks and negatively to non-technological shocks. Figures 13 and 14 provide the graphical counterpart of the previous evidence.

To clarify the historical decomposition, it is helpful to look at the impulse response functions estimated from the SVAR. Because of the similarity in the features, in Figures 15 and 16 we report only the responses of Italy and France.

[11] From our identifying restrictions, and from the specification of the VAR, we derive the correlations between productivity and employment conditional to the technological and non-technological shocks. Our results are similar to those reported in Hansen and Wright (1992), Christiano *et al.* (2003) and Basu *et al.* (2006). However, the evidence contrasts with other results which argue that hours worked fall after a positive technology shock (Galì, 1999). Following Galì (2004), our findings are based on the responses of total employment (full-time equivalent or persons) and total labor productivity to a positive technological shock. In our VAR model, this conditional correlation is positive. The growth rates of employment and productivity are stationary with no signs of any trend pattern for all the countries analyzed in the paper. Further, in one case we remove the different sample means of the growth rates of GDP before estimating labor productivity. The results of the different estimations are qualitatively similar. Including an intercept in the model implies that we allow variables in levels to grow around a trend. Thus, the intercept in first (log) differences VAR may be related to a linear deterministic trend in the levels, or to a unit root with drift in the level of variables. Because we tested our variables in levels for unit roots, and we have rejected the hypothesis of trend stationarity in favor of unit roots I(1), we do not include an intercept in the VAR. In addition, in our theoretical model any unexplained parts are not assumed to have a deterministic drift. If variables are I(1) without drift, or if theory suggests that changes in variables are explained by changes in other variables in the model, we do not need the VAR constant. Nonetheless, in the empirical analysis the sign of the conditional correlations is robust to the inclusion of the intercept. The change in sign only appears for Italy, Spain and UK when the number of lags becomes large, from five to eight lags. We also estimate the VAR model omitting the first five years. The empirical results remain practically unchanged.

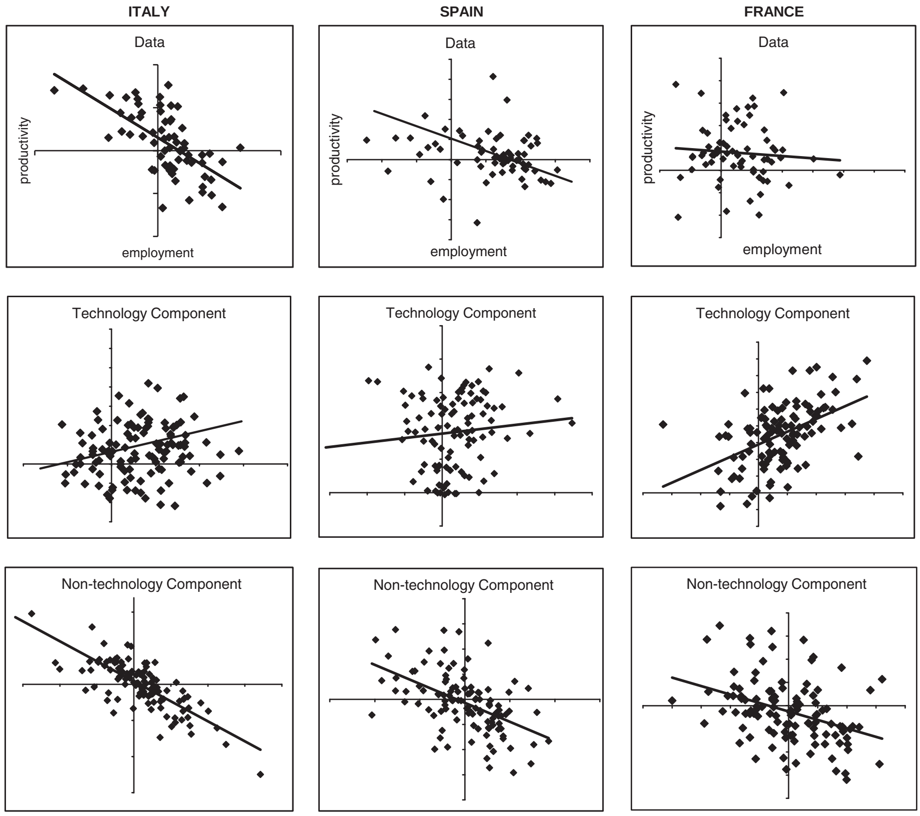

Figure 13. Productivity versus employment. Historical data, technological component, and non-technological component.

The impulse response functions for the other three countries are close to these. The main difference lies in the magnitudes of the responses. They give the response of the logs of productivity and employment to shocks in technology, institutions and aggregate demand.

The first two panels in Figures 15 and 16 show the responses of productivity and employment to a 1% long run increase in technology in the two countries. We interpret the impact of this shock as a shift of the labor demand curve along the supply curve. By construction the shock is positive. Note that productivity is positively correlated with the technological shock (Figure 15). Employment, on the other hand, decreases in the short run, but after two to three quarters the responses become positive (Figure 16). Notice that, in the long run, increases in technology have a positive but small impact on employment. A 1% shock has in the long run a 0.8% impact effect on employment. After seven to ten quarters, employment reaches 80% of their long run level. Instead, technological shocks increase in the long run productivity by 1.8% in Italy and by 1.5% in France. Thus, technology appears as the main source of the productivity dynamics, while it captures only a small share of the actual changes in employment.

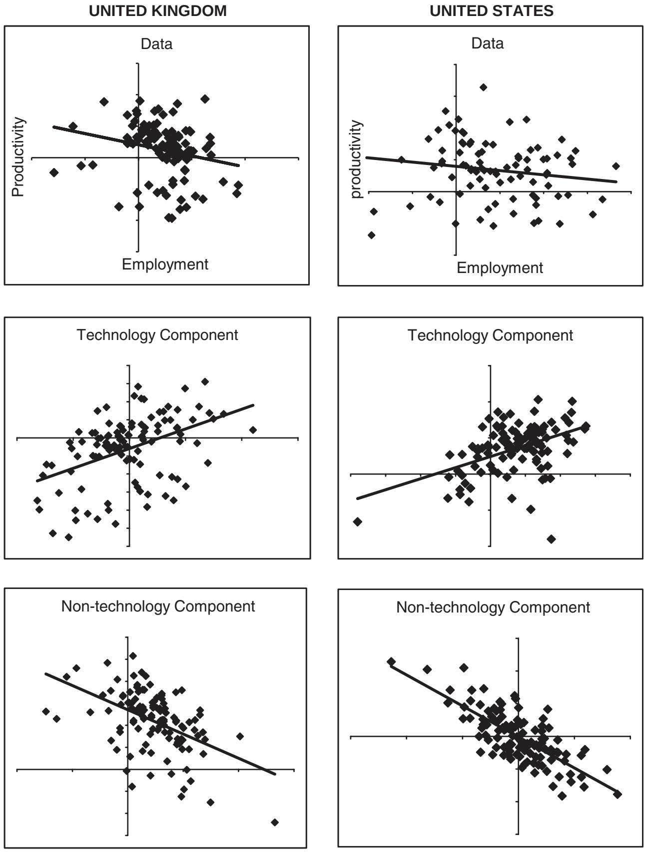

Figure 14. Productivity versus employment. Historical data, technological component, and non-technological component.

The second two panels in Figure 16 show that employment increases permanently to a non-*technological* shock, while the second two panels in Figure 15 show that productivity decreases temporarily in response to the same shock. We interpret these responses as the shift of the supply curve along the demand curve. The variations are coherent with the adjustment paths of the previous labor market model after a change in institutions. Non-technological shock leads to a stable increase in employment. The productivity response, on the other hand, is initially negative. A 1% shock in labor supply has a −0.3% impact effect on productivity in Italy; −0.5% in France. After four to five quarters, the non-technological shock leads to an increase in productivity of roughly 0.5–0.7%. Then, productivity returns to its original level. In the long run, the rise in (log) employment is associated with an unchanged level for (log) productivity.

Finally, the bottom two panels in Figures 15 and 16 give the responses of the growth rates of employment and productivity to a shock in aggregate demand. A 1% shock is initially associated with a positive effect on productivity. This is plausible since in short run an expansion of aggregate demand raises the level of

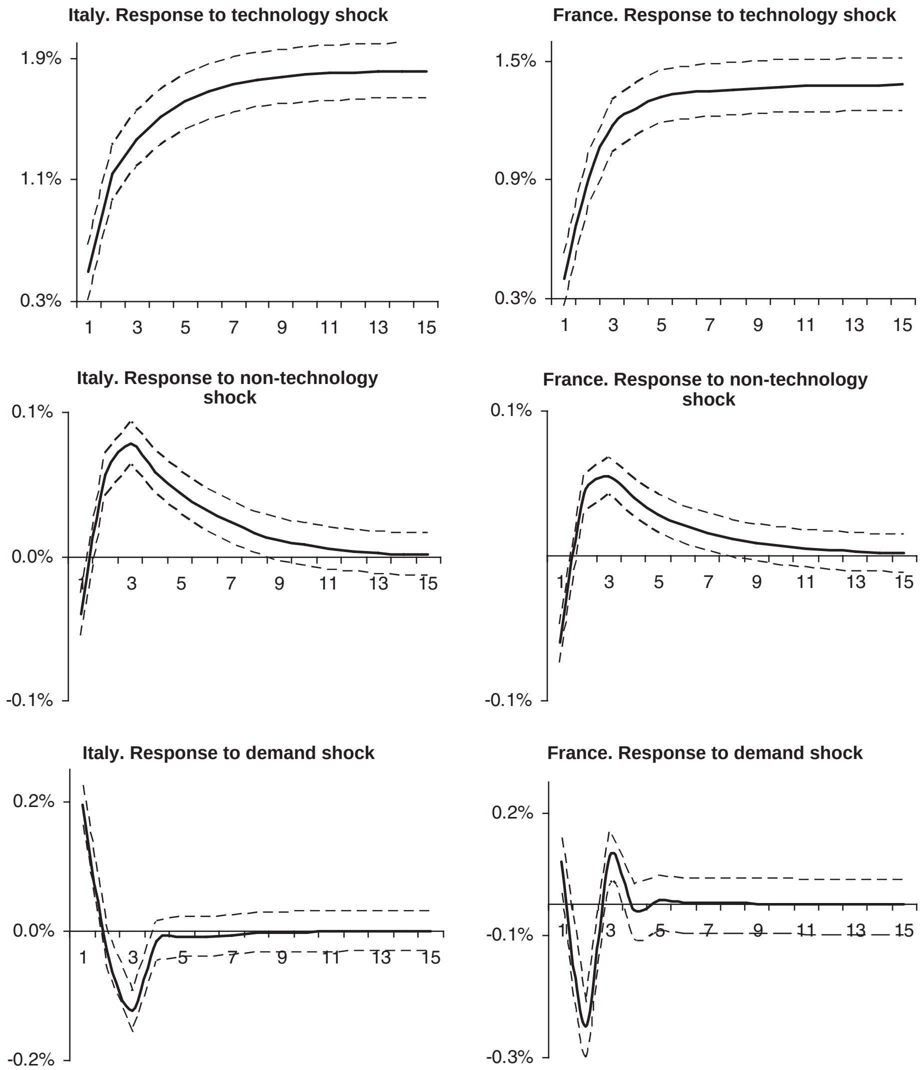

Figure 15. Productivity responses to shocks. Impulse responses to one standard deviation.
Note: Quarters on the horizontal axis.

GDP and capital utilization. On the other hand, employment reduces in the short run. However, as this initial impact fades away, productivity and employment converge to their original levels, so that the consequences of the aggregate-demand shock vanish over time.

Table 4 presents the forecast error variance decomposition. As before, we report values only for Italy and France. Technological shocks account for most of the variation in productivity. Specifically, they explain 79–86% of the variation in productivity at all horizons. Non-technological shocks account for 75–94% of the forecast error variance of employment.

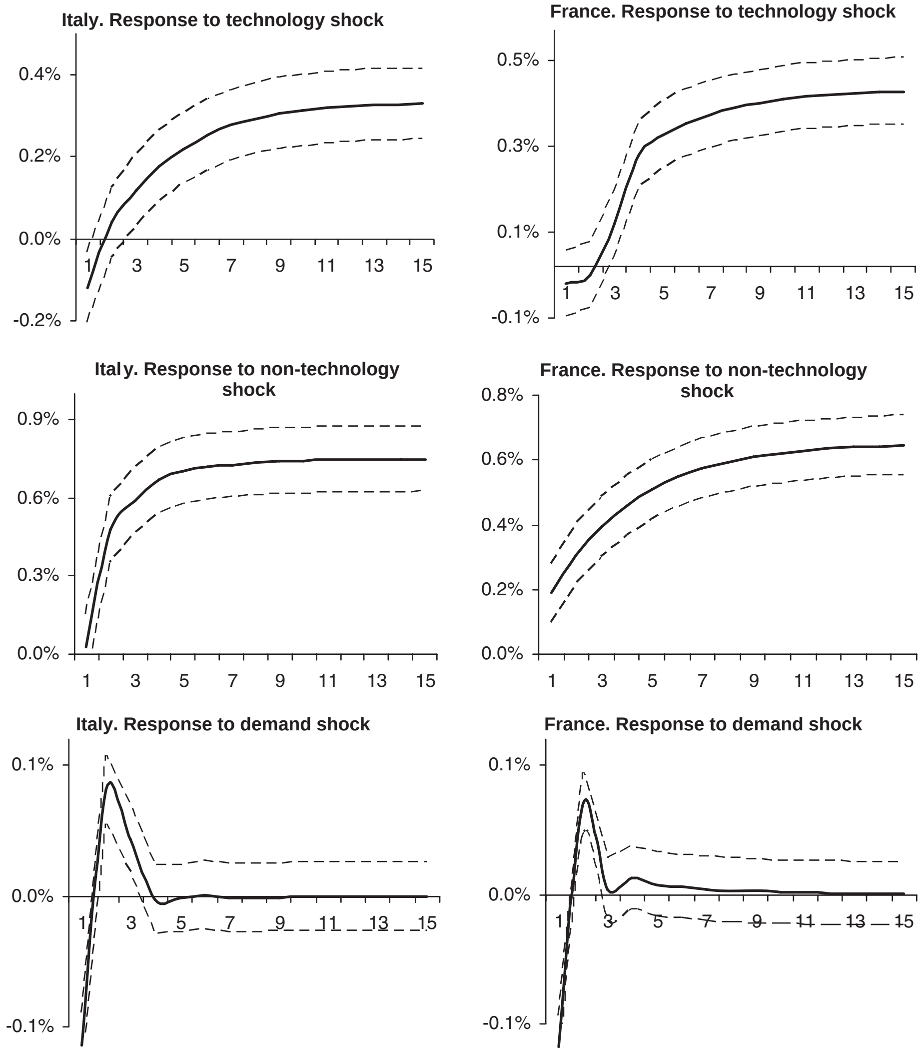

Figure 16. Employment responses to shocks. Impulse responses to one standard deviation.
Note: Quarters on the horizontal axis.

Note that for both productivity and employment only one shock captures most of the corresponding variation over time, with a negligible effect of the aggregate demand shocks (not reported in the table) in explaining the variance of variables. Thus, most of the productivity variation is due to technological shocks, with a marginal response to non-technological and aggregate demand shocks. Alternatively, employment variation is largely explained by non-technological shocks, with a minor effect for the other two shocks. Once again, this evidence confirms that both technological and non-technological shocks must be taken into account to explain the negative correlation between the growth rates of productivity and employment in the last 15 years.

Table 4. Forecast error variance decomposition

Productivity			Employment		
Periods ahead	Tech. shock	Non-tech shock	Periods ahead	Tech. shock	Non-tech shock
Italy			**Italy**		
1	79	13	1	0	94
5	81	12	5	5	87
15	83	12	15	6	86
France			**France**		
1	86	13	1	10	88
5	84	14	5	24	74
15	83	14	15	23	75

7. Conclusions

In this paper we have provided an explanation of the productivity slowdown across European countries during the last 15 years, focusing on the negative correlation between the growth rates of employment and productivity. We have found that shifts in both labor supply and demand are necessary to give a correct explanation of this negative trade off. The two shifts have contributed simultaneously to raise employment and to decrease the growth rate of productivity. This upshot has three main implications for the current debate on the European productivity slowdown.

First, the responses of productivity and employment to shocks are difficult to reconcile with theories focusing only on one side of labor market. A more helpful approach is to interpret the productivity slowdown as the result of shifts in labor supply and demand. The interaction between technological and non-technological shocks acts on the labor market equilibrium, by affecting productivity and employment.

Secondly, as said above, one interpretation of the basic facts we presented at the very beginning of our study is that firms reacted to labor market reforms in the 1990s by reducing capital deepening and hiring low quality labor. The initial effect of this choice has been to raise capital shares. However, moving away from skilled labor had the main consequence of decreasing the growth rate of technological progress with an adverse impact on both the growth rate of labor productivity and GDP. Hence, labor market reforms resulted in unintended and undesirable consequences for capital accumulation and productivity.

Thirdly, the predictions of our model provide a non-optimistic message about the future of the European economy. Actually, the rise in labor utilization might lead to slower capital accumulation and technological progress in the long run, with adverse consequences on both productivity and growth. Thus, the further outcome of our analysis is the policy implication that with two goals (employment and productivity) more than one instrument (labor market reforms) is needed to increase employment without depressing productivity. The policy to remedy to this situation appears much more complex than the ones drawn from the traditional labor supply explanation.

To conclude, we believe that the hypotheses employed in this paper are plausible. A comprehensive approach focusing on both sides of the labor market is needed. In this perspective, the European productivity slowdown puzzle can well be explained by the intricate interplay of technological and non-technological shocks in the labor market over the last 15 years.

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