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Estimating Potential Output with a Production Function for France, Germany and Italy *

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Résumé.

Dans ce papier, nous proposons une méthode d'estimation de la production potentielle par l'approche de la fonction de production pour la France, l'Allemagne et l'Italie pour la période 1986-2003. L'objectif de cette étude est double : d'une part, il s'agit de conserver un cadre d'analyse cohérent avec les secteurs institutionnels des comptes nationaux. D'autre part, après avoir identifié la productivité globale des facteurs (PGF) à partir du résidu de Solow, nous régtressonsla PGF sur une tendance temporelle corrigée des effets de l'âge du capital matériel et du taux d'utilisation des capacités de production. Cette méthode donne lieu à différentes considérations temporelles : du moyen au long terme, les variables supposées être à l'origine des fluctuations de court terme de la production potentielle sont considérées comme stables au niveau structurel. Ceci implique des modifications de la forme fonctionnelle donnée à la technologie de production selon l'horizon temporel considéré.

Mots-Clés : Croissance potentielle, fonction de production, productivité globale des facteurs, âge du capital matériel.

Classification JEL : C51, E32, O11, O47.

Abstract.

This paper discusses the supply conditions for economic growth in terms of potential GDP estimated by the production function approach for France, Germany and Italy for the 1986:2003 period. The aim of this study is twofold: first, we keep a consistent framework as regards national account institutional sectors. Second, after defining Total Factor Productivity (TFP) in the so-called productive sector from the Solow residual, we specify it in a general framework for the three countries as a function of a time trend corrected for the effects of the age of equipments and the capacity utilisation rate (CUR). This framework allows to distinguish temporal considerations: in the medium to long term, the variables that could generate short to medium term fluctuations in potential output growth are assumed to be stable at a structural level. This implies modifications of the functional specifications related to the time horizon.

Keywords: potential growth, production function, total factor productivity, age of equipments.

JEL classification: C51, E32, O11, O47.

Résumé non technique.

L'objectif de ce papier est de déterminer les raisons des différences de synchronisation des cycles d'affaires entre la France, l'Allemagne et l'Italie du point de vue de l'offre, en observant les capacités productives de long terme d'une économie et en mettant en évidence les différences entre les trois pays. Nous utilisons la méthode dite de la "fonction de production" afin d'estimer la croissance potentielle. Cette méthodologie se fonde sur une modélisation explicite de la technologie combinant les facteurs de production standards (travail et capital) ainsi qu'un progrès technique non observable. La notion de fonction de production semble plus appropriée pour les entreprises que pour le secteur non marchand. Ainsi, cette approche consiste à modéliser le secteur productif d'une économie, calibrer les paramètres clés sur la base de données pertinentes, déterminer le niveau de production potentielle relatif à cette calibration et modéliser le résidu de Solow afin d'expliquer ses variations, avec des outils économétriques. Ces estimations sont étendues à l'ensemble de l'économie dans un second temps, en introduisant le secteur non marchand.

Contrairement aux approches usuelles pour estimer la production potentielle de long terme, nous distinguons deux types d'horizon temporel, chacun associé à des conditions particulières de stabilité. Tout d'abord, dans le moyen terme, les principaux contributeurs à la croissance potentielle sont les facteurs traditionnels (capital et emploi), ainsi que la productivité globale des facteurs tendancielle. Ensuite, sur le sentier de croissance de long terme, l'économie croît en relation avec la tendance de long terme de la force de travail, la technologie et éventuellement la dérive des prix relatifs entre valeur ajoutée et investissement. En introduisant les prix relatifs, nous tenons compte de la stabilité de la productivité moyenne du capital en valeur plutôt qu'en volume, cette dernière étant fréquemment posée comme hypothèse de long terme. Cette séparation temporelle permet de mettre en regards différentes mesures de croissance potentielle. En conséquence, nous sommes capables de donner un diagnostic sur la position de l'économie dans le cycle aussi bien dans le moyen que dans le long terme et mettre ainsi en avant des indicateurs pouvant servir, dans le cadre d'autres études, à mesurer les tensions inflationnistes à différents horizons.

Les principaux résultats montrent que dans le moyen terme, la croissance potentielle de la France et de l'Allemagne est similaire en moyenne sur la période 1986-2003, s'établissant à

2.1% par an. Concernant l'Italie, la croissance potentielle apparaît inférieure de 0.5 point de pourcentage sur cette période. Sur les déterminants de la croissance potentielle, la comparaison des résultats montrent un certain contraste : pour la France et l'Allemagne, la croissance potentielle est principalement tirée par l'évolution de la productivité globale des facteurs et celle du secteur non marchand; pour la France, la contribution du capital est légèrement significative. Pour l'Italie, la croissance potentielle est largement expliquée par la croissance du capital et celui du secteur non marchand. Dans le long terme, la croissance potentielle de la France est restée globalement stable, proche de 2.5% sur la période. En Allemagne, après un seuil à 3% entre 1986 et 1998, la croissance potentielle a diminué pour atteindre 2% par la suite. Enfin, la croissance potentielle italienne de long terme a graduellement baissé sur tout l'horizon, de 1.5% environ en 1986 à 1% environ en 2003.

Non technical summary.

In this paper we aim at determining the causes of the lack of business cycle synchronization from a supply-side viewpoint between France, Germany and Italy by focusing on the long run production capacity of the economy and to point out the differences in the estimated potential output among the three countries. We use the so called production function approach in order to estimate potential growth. This methodology relies on an explicit modelling of the production technology such that economic growth is a function of standard factors of production (labour and capital) and an unobservable technological change. The notion of production function seems more appropriate as regards firms than as regards the public sector for instance. Thus, this approach consists in choosing a technical relationship supposed to represent the productive capacity of the economy (productive sector), calibrating key parameters on the basis of the relevant data, determining the level of potential output on the basis of this calibrated function and modelling the resulting Solow residual in order to explain its developments, using econometric techniques. Estimates are extended to the whole economy by introducing, in a second step, the government sector.

Contrary to the standard approach to estimate the long run potential output, we distinguish between two horizons, each one being associated with steady-state conditions. First, we consider medium term developments where the contributors to potential growth are the traditionally observed factors (actual capital and labour), as well as the Total Factor Productivity (TFP)

trend. Second, we analyze the long run steady-path where the economy grows in relation to the evolution of the long term trend of the labour force and the technology and eventually the ratio between value added prices and investment prices. These relative prices are incorporated in order to take into account, that over the sample, the capital intensity is stable in nominal terms rather than in real terms as often assumed. The separation of horizons provides useful measures of potential output. It offers a diagnosis on the position of the economy in the business cycle in both the medium term and the long term, and therefore indicators that could be used, in other studies, to assess inflationary pressures in the medium to long term.

The main result of our investigations is that the medium term potential growth for France and Germany appears to be similar in average over the 1986:2003 period, amounting to 2.1% per year. As for Italy, it seems to be outperformed by 0.5 percentage point. Focusing on the determinants of potential growth, results show more contrasted contributions. For both Germany and France potential growth is mainly driven by TFP and non productive sectors; for France also the contribution of capital is slighlty significant. As regards Italy, potential growth is largely explained by capital and the non productive sectors. In the long term, the potential growth of France remained roughly constant, close to 2.5% over the sample. In Germany, long run potential growth reached a plateau of about 3% between 1986 and 1998 and strongly declined to around 2% thereafter. For Italy, long run potential growth gradually decreased over the 1986:2003 period, from 1.5% to 1%.

1 Introduction

Recent developments in Europe have raised several interesting issues. Among them, one of paramount relevance concerns the existence of business cycle asymmetries between the three main countries of the euro area, namely France, Germany and Italy. The weak business cycle synchronization between these three countries is an important topic of concern since the determinants of such a lack of connection in Europe are far from being clearly established. Consequently, this raises the question whether business cycle asymmetries between France, Germany and Italy are temporary or structural.

An interesting approach to determine the causes of the lack of business cycle synchronization between France, Germany and Italy is to focus on the long run production capacity of the economy and to point out the differences in the estimated potential output among the three countries. Indeed, the identification of factors driving potential growth will allow to structurally explain asymmetries in business cycles from supply-side developments.

In line with Solow's neoclassical model, we use the so-called production function approach in order to estimate potential growth. This methodology relies on an explicit modelling of the production technology such that economic growth is a function of standard factors of production (labour and capital) and an unobservable technological change. The notion of production function seems more appropriate as regards firms than as regards the public sector for instance. Thus, this approach consists in choosing a technical relationship supposed to represent the productive capacity of the economy (productive sector), calibrating key parameters on the basis of the relevant data, determining the level of potential output on the basis of this calibrated function and modelling the resulting Solow residual in order to explain its developments, using econometric techniques. Estimates are extended to the whole economy by introducing, in a second step, the government sector (that we label 'non productive sector'). Nevertheless, it is worth noting that this more sophisticated approach applied to the productive sector implies a higher burden in terms of data requirements. In most cases, several pieces of information are available only for France (*e.g.* productive capital stock, household employment); corresponding series for Germany and Italy have been estimated by introducing assumptions that may be somewhat arbitrary.[1]

Contrary to the standard approach to estimate the long run potential output, we distinguish two horizons, each one being associated with steady-state conditions. First, we consider medium term developments where the contributors to potential growth are the traditionally observed factors (actual capital and labour), as well as Total Factor Productivity (TFP) trend. Second,

[1] See Appendix Sections for more details.

we analyze the long run steady-path where the economy grows in relation to the evolution of the long term trend of the labour force and the technology and eventually the ratio between value added prices and investment prices. These relative prices are incorporated in order to take into account, that over the sample, the capital intensity is stable in nominal terms rather than in real terms as often assumed. This separation of horizons will provide useful measures of potential output. Thus, we will be able to give a diagnosis about the position of the economy in the business cycle in both the medium term and the long term, and therefore indicators of inflationary pressures in the medium to long term.

The main result of our investigations is that the medium term potential growth for France and Germany appears to be similar in average over the period 1986-2003, amounting to 2.1% per year. As for Italy, it seems to be outperformed by 0.5 percentage point. Focusing on the determinants of potential growth, results show more contrasted contributors. For both Germany and France potential growth is mainly driven by TFP and non productive sectors; for France also the contribution of capital is slighlty significant. As regards Italy, potential growth is largely explained by capital and the non productive sectors. In the long term, the potential growth of France remained roughly constant, close to 2.5% over the sample. In Germany, long run potential growth reached a plateau of about 3% between 1986 and 1998 and strongly declined to around 2% thereafter. For Italy, long run potential growth gradually decreased over the period 1986-2003, from 1.5% to 1%.

The structure of the paper is as follows. In Section 2, we present the theoretical framework and lay out the method for estimating potential output. In Section 3, we discuss the results and some concluding remarks are made in Section 4. A description of the construction of capital stock series and the database for the three countries is given in the Appendix.

2 Theoretical framework

2.1 General overview

We consider that the production technology in the productive sector of one economy can be represented by a Cobb-Douglas production function with constant return to scale on labour and capital. Analytically, the production function can be expressed in logarithms as follows:

$$q_t = (1-\alpha)k_t + \alpha l_t + g_t,$$

where q_t, k_t and l_t are, respectively, the real value added, the stock of productive capital and the labour input (measured in hours worked) in the productive sector, α $(0 < \alpha < 1)$ represents the wage share in the value added of the productive sector and g_t is Total Factor Productivity.

The other gross domestic product (GDP) components, namely value added of households, non profit institutions serving households (NPISH), public administrations and institutions and indirect taxes net of subsidies are smoothed by means of an Hodrick-Prescott (HP) filter and then added to the potential value added of the productive sector to build up the potential GDP of the whole economy.

A two-step approach is adopted. First, the labour share is set at its average level over the sample to define the TFP, as the Solow residual of the neoclassical model:

$$g_t = q_t - (1-\alpha)k_t - \alpha l_t.$$

Second, following de Bandt and Rousseaux (2002), the impacts of the determinants of TFP, around a time trend, are estimated using the following specification:

$$g_t = \gamma_0 + \gamma_1 g_{t-1} + \gamma_2 t + \gamma_3(cur_t - \overline{cur}) + \gamma_4(\tau_t - \bar{\tau}) + \gamma_5 \tilde{t} + \varepsilon_t, \tag{1}$$

where cur_t is the capacity utilisation rate (CUR), in logs, and $\overline{cur}$ is the corresponding average level, τ_t is the age of the capital stock of equipment goods, in logs, and $\bar{\tau}$ is the corresponding average level. ε_t is an error term.

The deterministic trend t is considered assuming that the technical change is exogenous so that TFP grows at a constant rate. The term $\tilde{t} = \mathbb{I}(t > t^*)(t - t^*)$ is introduced in order to capture a possible country-specific break in the rate of change at date t^*.[2] γ_3 measures the cyclical component of the TFP. We expect that TFP grows as the domestic production capacities are used more intensively than usual, so the parameter γ_3 should be positive. Moreover, an ageing stock of capital as compared to its average age, could impact negatively on the TFP such that the parameter γ_4 should be negative. Finally, an autoregressive term is introduced to capture inertia in TFP changes. The break in trend is omitted in the two following subsections ($\gamma_5 = 0$).[3]

2.2 Medium term developments

2.2.1 Total Factor Productivity

Uncovering the TFP trend in the medium run requires two assumptions. First, we assume that the growth rate of the TFP, ρ, is constant. This rate is estimated by the average growth rate over the period. Second, the capacity utilisation rate is assumed to be at its average level so that the gap between cur_t and $\overline{cur}$ is null.

From the first assumption, we can write medium run TFP (in logs) as $\tilde{g}_t = \tilde{g}_{t-1} + \rho$. So,

$$\tilde{g}_t = \tilde{g}_{t-1} + \rho = \gamma_0 + \gamma_1 \tilde{g}_{t-1} + \gamma_2(t - 1 + 1) + \gamma_4(\tau_t - \bar{\tau}),$$

[2] The indicator function $\mathbb{I}(.)$ is defined as $\mathbb{I}(A) = 1$ if A is true and $\mathbb{I}(A) = 0$ otherwise.

[3] See Section 3.

$$(1-\gamma_1)\tilde{g}_{t-1} = (\gamma_0 - \rho + \gamma_2) + \gamma_2(t-1) + \gamma_4(\tau_t - \bar{\tau}),$$

which gives the following period:

$$(1-\gamma_1)\tilde{g}_t = (\gamma_0 - \rho + \gamma_2) + \gamma_2 t + \gamma_4(\tau_{t+1} - \bar{\tau}).$$

This last equation defines the medium term TFP:

$$\tilde{g}_t = \frac{\gamma_0 - \rho + \gamma_2}{1-\gamma_1} + \frac{\gamma_2}{1-\gamma_1} t + \frac{\gamma_4}{1-\gamma_1}(\tau_{t+1} - \bar{\tau}). \tag{2}$$

In the medium run, the TFP evolves around a trend and a measure of capital ageing. We assume that inflexions due to capital stock ageing or replacement sluggishly disappear at a slower pace than those caused by CUR variations. These inflexions impact on TFP and last over the medium term. However, the effect of capital ageing vanishes in the long run.

2.2.2 Labour input

After computing the medium term TFP, we have to estimate potential labour input. As we consider labour input in hours worked, we first smooth hours worked, h_t. The potential employment in the productive sector is defined by:

$$N_t^* = \Omega_t^* r_t^* (1-u_t^*) - (N_t^{H\,*} + N_t^{P\,*} + N_t^{\text{NPISH}\,*}), \tag{3}$$

where $N_t^{H\,*}$, $N_t^{P\,*}$ and $N_t^{\text{NPISH}\,*}$ are respectively smoothed series of employment in household sector, public sector and NPISH sector. Ω_t^*, r_t^* and u_t^* represent respectively the filtered working age population, the filtered medium term participation rate and the non-accelerating inflation rate of unemployment (NAIRU). In order to derive smoothed components, the HP filter has been always used, with standard value for the smoothing parameter ($\lambda = 1600$, since we are dealing with quarterly data, except for the hours worked – where $\lambda = 20000$ – and the NAIRU (see appendix for sources)).[4]

As regards levels, in the medium term, potential real value added in the productive sector is given by:

$$Q_t^{prod\,*} = K_t^{(1-\alpha)} (N_t^* h_t^*)^\alpha e^{\tilde{g}_t}. \tag{4}$$

Then, we add contributions to GDP from the other sectors as well as net indirect taxes to construct the potential GDP Y_t^* of the whole economy:

$$Y_t^* = Q_t^{prod\,*} + Q_t^{H\,*} + Q_t^{P\,*} + Q_t^{\text{NPISH}\,*} + T_t^*, \tag{5}$$

where $Q_t^{H\,*}$, $Q_t^{P\,*}$ and $Q_t^{\text{NPISH}\,*}$ are the filtered value added series respectively of households, of the public sector and of NPISH, and T_t^* the filtered series of net indirect taxes. These series are smoothed with an HP filter ($\lambda = 1600$).

[4]We choose a non-standard value for the smoothing parameter related to hours worked in order to eliminate any cyclical evolution of filtered data.

2.2.3 Contributions to potential growth

We first define the quarterly year-on-year growth rate of potential GDP by:

$$g_{Y^*,t} = \frac{Y_t^*}{Y_{t-4}^*} - 1.$$

Then we specify the share of the potential GDP associated to the non-productive sectors and taxation as:

$$\theta_t = \frac{Q_t^{H\ *} + Q_t^{P\ *} + Q_t^{\text{NPISH}\ *} + T_t^*}{Y_t^*}.$$

So, the contribution of the capital stock of the productive sector to whole economy potential GDP growth is given by:

$$\sigma_{K,t} = (1-\alpha)(1-\theta_{t-4})g_K,$$

with g_K the year-on-year growth rate of capital stock.

In the same way, the following equation defines the contribution to potential growth of employment in the productive sector:

$$\sigma_{N^*h^*,t} = \alpha(1-\theta_{t-4})g_{N^*h^*},$$

where g_{N^*} is the growth rate of potential employment in the productive sector.

The contribution of the non-productive sectors can be written as follows:

$$\sigma_{Q^{\text{NPS}},t} = \theta_{t-4}g_{Q^{\text{NPS}}},$$

where $g_{Q^{\text{NPS}}}$ is the growth rate of the value added of the non-productive sectors ($Q^{\text{NPS}} = \theta_t Y_t^*$).

Since changes in the age of the capital stock around its average level are taken into account to model TFP, two terms define the TFP's contribution. The first one consists in the contribution of the time trend as in equation (2):

$$\sigma_{trend} = 4(1-\theta_{t-4})\frac{\gamma_2}{1-\gamma_1}.$$

As original series are expressed on a quarterly frequency, a coefficient 4 is introduced to measure annual contribution. The second term represents the contribution of the age of the capital stock:

$$\sigma_{\tau,t} = (1-\theta_{t-4})g_{\tilde{\tau}},$$

with $g_{\tilde{\tau}}$ the year-on-year growth rate of $\tilde{\tau}$ which is given by:

$$\tilde{\tau} = \exp(\frac{\gamma_4}{1-\gamma_1}(\tau_t - \bar{\tau})).$$

Thus, the total contribution of the TFP can be written as follows:

$$\sigma_{\text{TFP},t} = \sigma_{trend,t} + \sigma_{\tau,t}.$$

Finally, we obtain the following breakdown in contributions to whole economy potential GDP growth, which will be analyzed in section 3.2:

$$g_{Y^*,t} = \sigma_{K,t} + \sigma_{N^*h^*,t} + \sigma_{Q^{\text{NPS}},t} + \sigma_{\text{TFP},t}. \tag{6}$$

2.3 Long run developments

In the long run, we impose several additional assumptions. First, the age of the capital stock tends towards its average level, leading us to disregard the contribution of age to potential growth.[5] Then, we consider that employment and potential value added of the non-productive sectors grow at the same rate as in the productive sector. Moreover, we set the participation rate r_t^*, NAIRU u_t^* and the worked hours h_t to their average level. Finally, we assume that the output/capital ratio is stable in nominal terms over all the sample.[6] This last assumption drives us to consider the following equation:

$$\frac{p_{q,t} Q_t^{prod}}{p_{I,t} K_t} = \zeta, \tag{7}$$

where $p_{q,t}$ and $p_{I,t}$ are respectively the value added and investment deflators in the productive sector and ζ is a constant. As we can see in Fig. 1, this stylized fact is met for France and Italy but could be less relevant in the case of Germany.

Combining equations (4) in logs and the definition of TFP in (2), we find:[7]

$$\Delta_4 q_t^{prod\,*} = (1-\alpha)\Delta_4 k_t + \alpha \Delta_4 n_t^* + 4\frac{\gamma_2}{1-\gamma_1}. \tag{8}$$

Moreover, according to equation (7), we have:

$$\Delta_4 k_t = \Delta_4 q_t^{prod\,*} + \Delta_4 \ln\left(\frac{p_{Q,t}}{p_{I,t}}\right). \tag{9}$$

As productive and non-productive sectors are growing at the same rate, the long term potential GDP growth is given by substituting (9) in (8):

$$g_{Y^*,t}^{lt} = \Delta_4 q_t^{prod\,*} = \frac{(1-\alpha)}{\alpha}\Delta_4 \ln\left(\frac{p_{Q,t}}{p_{I,t}}\right) + \Delta_4 n_t^{prod\,*} + \frac{1}{\alpha}\frac{4\gamma_2}{1-\gamma_1}.$$

Furthermore, as the participation rate, the time-varying NAIRU and the worked hours are supposed to be constant in the long run, the annual growth rate of potential employment is given by variations in working age population. As a consequence, the potential GDP growth in the long run is given by:

$$g_{Y^*,t}^{lt} = g_{\Omega^*,t} + \frac{1}{\alpha}\frac{4\gamma_2}{1-\gamma_1} + \frac{(1-\alpha)}{\alpha}\Delta_4 \ln\left(\frac{p_{Q,t}}{p_{I,t}}\right). \tag{10}$$

[5] We can show that on a balanced growth path, the age of the capital stock corresponds to the inverse of the depreciation rate plus the growth rate of the economy.

[6] See Jorgenson and Stiroh (1999), Cette et al. (2005) for more details.

[7] Δ_4 operator is defined by $\Delta_4 x_t = x_t - x_{t-4}$ and corresponds to the year-on-year growth rate of variable X_t.

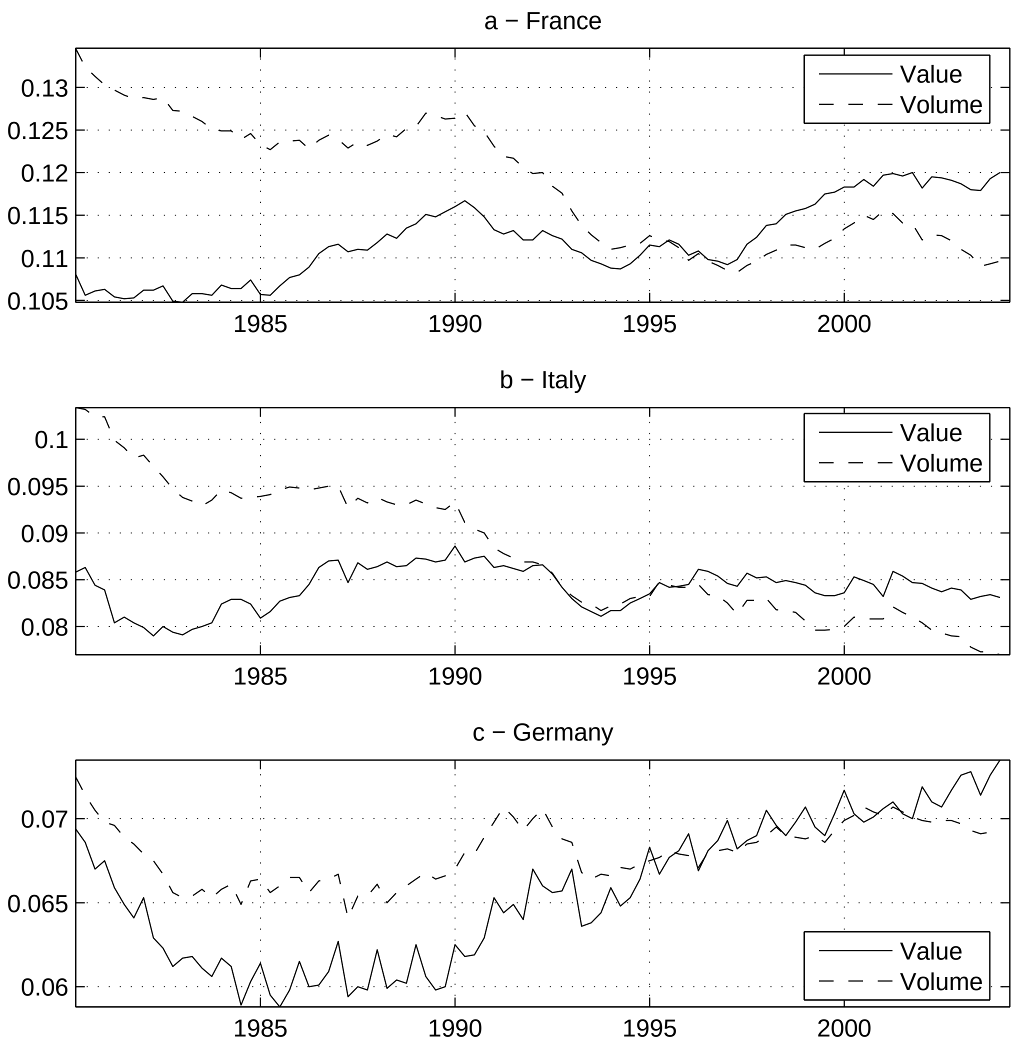

Figure 1: Output/capital ratio

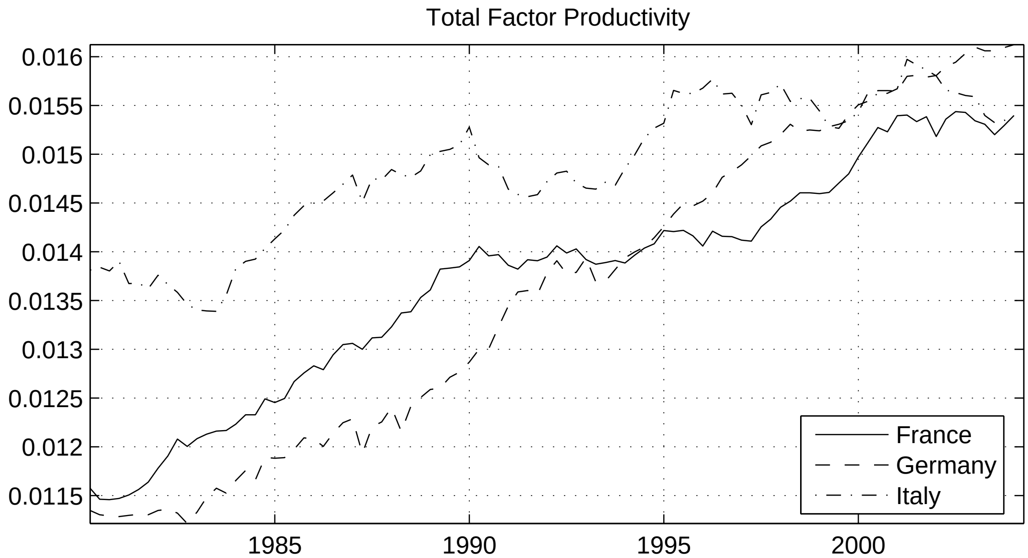

Figure 2: Estimated level of TFP, $\exp(\tilde{g})$

The growth rate of the economy is driven by the growth rate of the population $g_{\Omega^*,t}$, the value of the trend of TFP and the drift in relative prices. It is worthwhile to mention that the TFP trend contributes differently to the potential growth depending on the time horizon: as we assumed that the economy evolves on its steady growth path in the long run, the contribution of TFP corresponds analytically to the trend divided by the share of labour, which is lower than one. As a result, the contribution of TFP appears higher in the long run than in the medium term.[8]

3 Results and comparative estimates

3.1 Estimates for the TFP

Before estimating the TFP components, the parameter α is set to the sample average share of wages in value added for the productive sector. The resulting values of α for France, Germany and Italy are respectively 0.72, 0.74 and 0.65. Fig. 2 represents the resulting estimates of TFP for the three countries. One of the advantages of this method lies in its homogeneity that allows to obtain comparable levels of TFP. Taking capital and labour as given, we are therefore able to distinguish the economies according to their productive performance. Furthermore, these first results suggest that during the period 1980-1999, Italy has the higher level of TFP among the three countries, before being caught up by Germany and then France in the last years of the sample.

[8] We could have avoided the introduction of α in the expression of the long run GDP growth by considering the TFP as a Harrod-neutral technological change.

Estimations by Ordinary Least Squares (OLS) of the TFP parameters of regression (1) are presented in Table 1 for each country.[9] All coefficients are significant. The signs of estimated

Table 1: Estimations of the TFP for the three countries

Country	γ_0 intercept	γ_1 g_{t-1}	γ_2 t	γ_3 $cur_t - \overline{cur}$	γ_4 $\tau_t - \bar{\tau}$	γ_5 $\tilde{t}$
France	-1.6136	0.6365	0.0011	0.1621	-0.1638	-
	(0.3259)	(0.0732)	(0.0002)	(0.0296)	(0.0595)	
Germany	-0.7667	0.8292	0.0007	0.0478	-	-
	(0.2380)	(0.0527)	(0.0002)	(0.0206)		
Italy	-0.6240	0.8531	1.36E-4	0.0991	-	-
	(0.2393)	(0.0561)	(7.81E-5)	(0.0416)		

In parenthesis are given the estimated standard errors.

parameters are consistent with our expectations: coefficients are positive for the trend and the capacity utilisation rate, negative for the age-gap. In order to uncover potential breaks in TFP equation (1), we carried out the Bai-Perron (1998) test. This procedure allows both to test the number of multiple unknown structural changes and to estimate the location of the breaks. As a result, no break was found for each of the three countries whatever the variable assumed to have a time-varying impact on TFP, according to the Bai-Perron terminology.

Concerning the estimation of parameter related to age of capital, France only presents a significant contribution of this variable. According to the definition of medium term TFP in equation (2), a one-year younger equipment capital stock, which corresponds to a decrease by about 14.3% for an average of 7 years, leads to an increase of the TFP growth rate by approximatively 6.4 points. This assessment is quite close in terms of magnitude to other estimates in the literature.[10]

As regards the trends, our estimates correspond to medium term growth rate of 1.2%, 1.6% and 0.4%, respectively for France, Germany and Italy. The difference between Italy and the other countries seems to be a potential source of structural gap in productivity.

3.2 Potential growth and contributions in the medium term

The following table (Tab. 2) shows the different contributions resulting from equation (10) of each component of potential output from 1986 to 2003 for France, Germany and Italy. In the period 1986-2003, the average annual growth rate of potential output is 2.1% for France and Germany, and 1.6% for Italy. As regards the results for France, the main contributor to potential growth appears to be related to the non productive sectors (public sector, households

[9] In order to obtain economically meaningful estimated coefficients, the estimation period for France and Germany runs from 1986Q1 to 2003Q4, whereas for Italy it begins in 1980Q1.

[10] Based on different approach and samples, Cette and Szpiro (1989) assess this impact to 3.6 points.

and NPISH) and reaches 0.9 percentage point over the period. Contribution of labour in the productive sector is insignificant and the stock of capital and TFP contribute positively by respectively 0.5 percentage point and 0.7 percentage point. Concerning Germany, potential growth is mainly driven by the TFP with 1.3 pp of contribution. The contributions of capital (0.3 percentage point), labour in the productive sector (-0.2 percentage point) and the other sectors (0.6 percentage point) are the lowest among the three countries. For Italy, Tab. 2 shows the large contribution of the non productive sectors (0.8 percentage point) to potential growth. The contribution of capital is the highest among the three countries and amounts to 0.7 percentage point. Labour in the productive sector contributes negatively by -0.1 percentage point to the potential growth. At this stage, TFP appears to be the most striking factor to distinguish between France, Germany and Italy in terms of potential growth. Figure 3

Table 2: Contributions to the average potential growth rate from 1986 to 2003 in percentage

Period	pot. growth	capital	labour	others	TFP$^{(*)}$
			France		
1986 to 1989	2.1	0.6	-0.1	0.8	0.8
1990 to 1994	1.9	0.5	-0.2	1.0	0.6
1995 to 1999	1.9	0.4	-0.0	1.0	0.6
2000 to 2003	2.5	0.5	0.3	0.8	1.0
1986 to 2003	2.1	0.5	-0.0	0.9	0.7
			Germany		
1986 to 1989	2.3	0.5	-0.3	0.7	1.4
1990 to 1994	2.4	0.4	-0.0	0.6	1.4
1995 to 1999	1.9	0.2	-0.2	0.5	1.4
2000 to 2003	1.7	0.2	-0.4	0.5	1.4
1986 to 2003	2.1	0.3	-0.2	0.6	1.4
			Italy		
1986 to 1989	1.9	0.8	-0.3	1.1	0.3
1990 to 1994	1.6	0.7	-0.3	0.9	0.3
1995 to 1999	1.7	0.5	-0.0	0.9	0.3
2000 to 2003	1.4	0.7	0.2	0.3	0.3
1986 to 2003	1.6	0.7	-0.1	0.8	0.3

(*) Including age of capital for France.

depicts the country-specific time-series profile of the main components of potential growth in the medium term. From this figure, we can also notice that a marked decrease in medium term potential growth took place in the middle of the 1990´s. Thus, there remains at this horizon some cyclical patterns, for example the contraction of 1993-1994 in Europe.

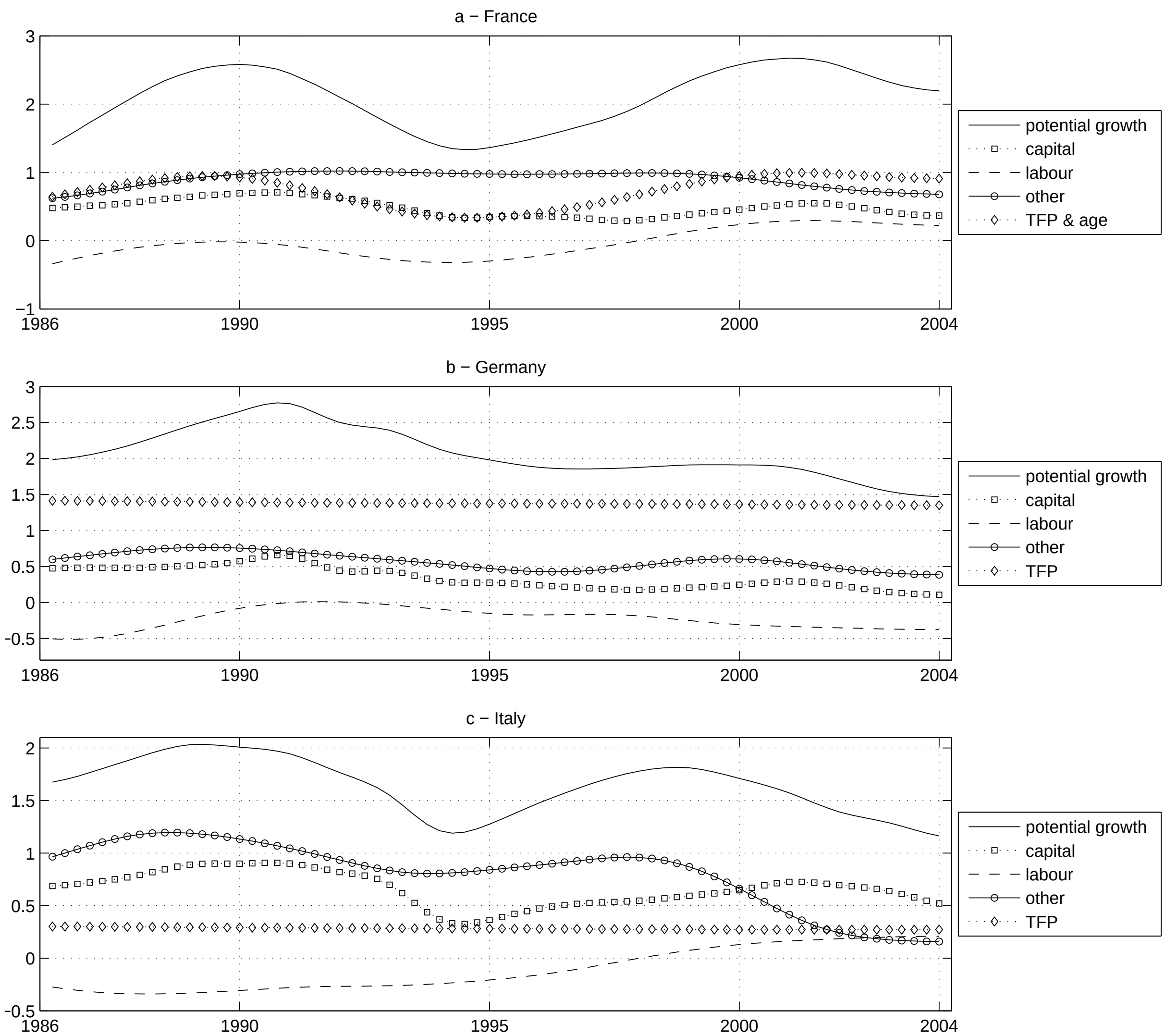

Figure 3: Contributions to the medium term potential growth, percentage points

3.3 Potential growth and contributions in the long run

Figure 4 presents the country-specific time-series profile of the main components of potential growth in the long run, derived from equation (10).

In the long term, potential growth in France stayed roughly around the level of 2.5% over the sample. The relative price drift explains part of the decrease in potential growth, this effect being of structural nature. In Germany, long run potential growth remained around 3% between 1986 and the second quarter of 1991, and then gradually diminished until reaching 2.2% in 2003. For Italy, long run potential growth gradually declined over the period 1986-2003, from 1.5% to 1%. This decrease is largely linked to the gradual reduction in potential employment over the period. For this country, the difference with medium term growth is explained by the discrepancy in real value added growth between the productive sector and the non productive sectors.

4 Concluding remarks

The analysis of output growth in the three major euro area economies undertaken in this paper suggests that in the medium term, France and Germany experienced an identical average potential output growth over the last 20 years. Italy stands out as the country witnessing a slower growth. All three countries benefited, albeit to different extents, from the buoyant contribution of non-productive sectors over the period. In contrast to Italy, the contribution of TFP to the potential output growth in France and Germany was found clearly significant. In France and Germany, the contribution of capital appears to be weak, whereas in Italy this factor contributes at a higher and steady level over the sample. Over the 2000-2003 period, however, potential growth decreased in Germany and Italy while it increased in France. In the long term, the growth divergences between these economies tend to disappear, especially between France and Germany since the long term pace of growth is estimated at about 2 to 2.5% for both countries. For Italy, the long run potential growth amounts to 1% at the end of the sample and leads to the conclusion that weak Italian output developments over the period as compared to the two other countries comes from structural sources.

An interpretation of these divergent growths which prevail in the three major euro area economies, may be, besides the differences in economic performances, the differing macroeconomic policies. Moreover, although a comprehensive discussion of these mechanisms is out of the scope of the paper, microeconomic studies would potentially allow to evaluate to which extent factors such as the adoption of the information and communication technology, the sector-level

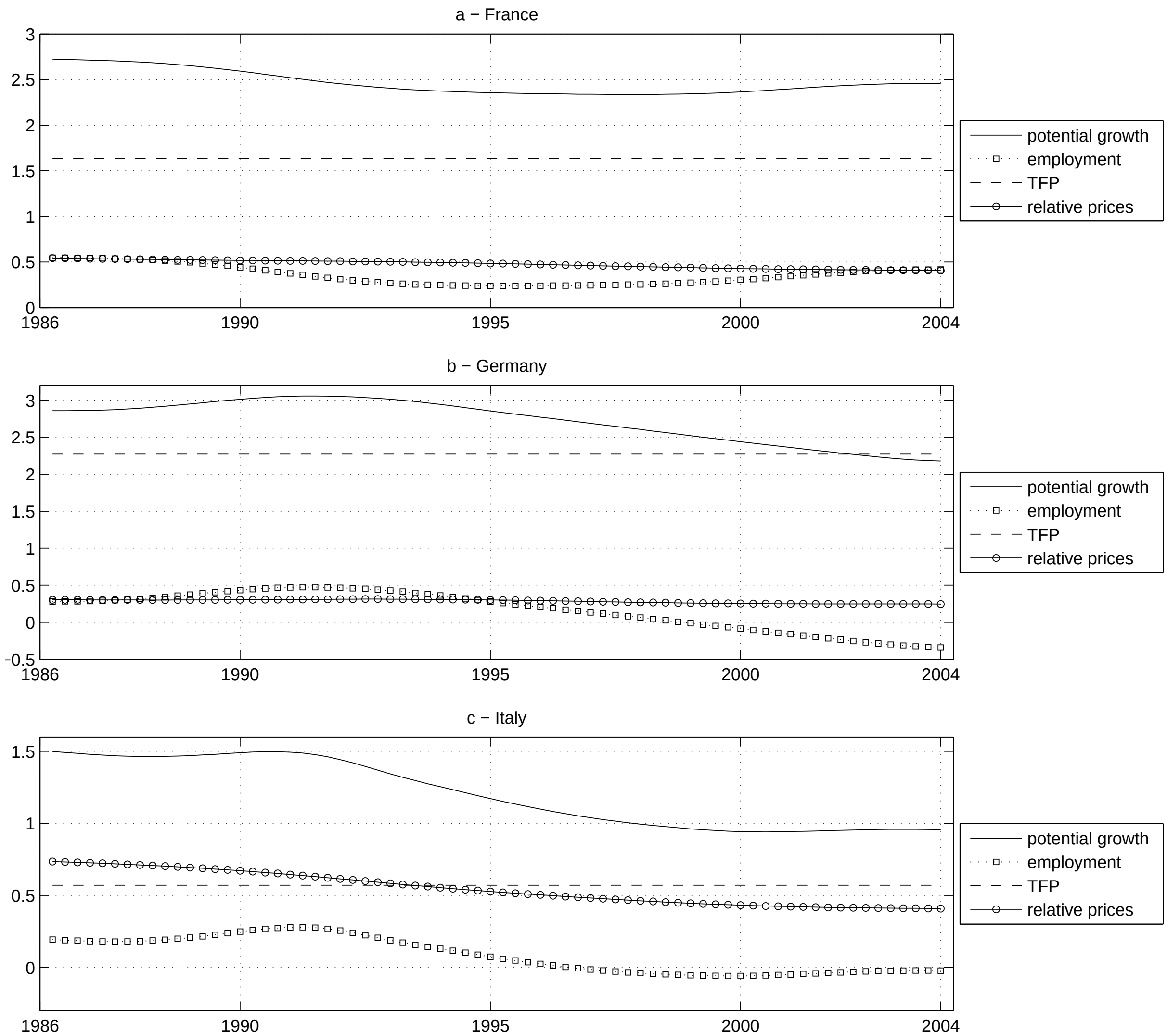

Figure 4: Contributions to the long run potential growth, percentage points

labour cost, firm-level tax burden or the impact of R&D intensity affect the engine of economic growth. Moreover, this microeconomic approach should permit to model together the three countries within a panel data framework.

Another interesting way of research would be to focus on the non-productive sectors in order to better distinguish the sources of differences and their impacts on the economy. If some gaps are found, this would be extremely informative for the medium and long term diagnosis on the convergence of European economies.

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A Appendix : Construction of capital stock time series

Capital stock data are very dependent on the methodology adopted by national statistical institutes and can vary subsequently across countries.

In the framework of this paper, we propose to use capital stock series built according to a methodology elaborated by Villetelle (2002) for France. This methodology, which uses as input only national account data on the average service life of capital goods (equipment and buildings), is easy to implement. Based on the perpetual inventory method (PIM), it requires however long investment time series. In addition to making capital stock data more comparable, this method uses an age-efficiency profile which has the advantage of defining a *productive* capital stock which is more relevant for the estimation of potential growth by a structural approach. This appendix describes the different steps required to get the *underlying* capital stock on the basis of

Table 3: Average duration of capital and depreciation rate

Equipments		Constr. excl. Housing		Housing	
Deprec. rate (%)	Average duration (years)	Deprec. rate (%)	Average duration (years)	Deprec. rate (%)	Average duration (years)
9.50	10.5	1.50	66.7	1.00	90.9

a minimum number of assumptions. The result is nevertheless not easily tractable. In particular the *underlying* capital stock yields a non-constant depreciation rate δ_t.

The approach that we suggest is then based on a geometric approximation of the law of motion of capital:

$$K_t = I_t + (1-\delta)K_{t-1} = (1-\delta)^t K_0 + \sum_{j=0}^{t} (1-\delta)^j I_{t-j}. \tag{11}$$

We calibrate the constant depreciation rate δ that locally better approximates for the best the profile of the *underlying* capital stock.

Table 3 gives the final output. The initial capital stock is estimated by fitting the geometric law of motion to the *underlying* capital stock for the final part of the sample.[11]

A.1 Main ingredients

Different definitions of capital stock are possible. We concentrate on the concept of *productive* capital, but define before gross and net capital. The gross capital stock measured at date t is the sum of past investment (from $t = 0$ to $t = T$, *i.e.* until maximum lifetime) weighted by survival probabilities. Each investment flow is valued at *as new* prices regardless of the age and actual condition of the assets:

$$K_t^G = \sum_{i \geq 0} s_i I_{t-i},$$

with K_t^G indicating the gross capital stock at the date t at the base year price, I_t the investment flows between $t-1$ and t at the base year price and s_i the survival rate at t of past investment made between $t-i-1$ and $t-i$.

The net capital stock measured at the date t takes into account the *consumption of fixed capital* defined as the decline, during the course of the accounting period, in the current value of the stock of fixed assets as a result of physical deterioration, normal obsolescence or normal accidental damage.

$$K_t^N = \sum_{i \geq 0} \nu_i I_{t-i},$$

[11] Actually, the depreciation rate δ is taken as the average depreciation rate on the period for which the capital stock can be computed, given that data for investment are required for T periods, where T, to be defined thereafter, is the maximum lifetime.

with K_t^N indicating the net capital stock t at the base year price and ν_i the valuation of an i-period asset over its remaining duration life valuation at the base year price.

We introduce the concept of *productive* capital which allows us to take into account a decreasing efficiency of surviving assets over the time.

$$K_t^P = \sum_{i \geq 0} s_i e_i I_{t-i}, \tag{12}$$

with K_t^P the productive capital stock t at the base year price, s_i the survival rate at t of a i-period asset and e_i the efficiency of a i-period old asset.

That way, in addition to the survival function used for the gross capital stock, we use an other rule indicating how investment efficiency decreases over age (age-efficiency profile).

A.2 Specific assumptions on mortality and efficiency over time

A.2.1 Mortality function

We use as mortality function a delayed linear function. Delay is arbitrarily set to 1/3 of the total life duration. The average service life is taken from the national accounts. According to this pattern, the coefficients of the survival function (see Fig. 5a) are:

$$s_i = \begin{cases} 1 & , \ 0 \leq i \leq \frac{T}{3} - 1 \\ 1 - \frac{i - T/3}{T - T/3} & , \ \frac{T}{3} \leq i \leq T \end{cases},$$

with T the maximum duration life, defined on the basis of the average duration life M and the above assumptions as the solution of $M = \frac{2}{3}T + \frac{1}{2}$. Figure 5b draws the mortality function, which represents the probability density function of age.

A.2.2 Age-efficiency profile

In line with some statistical offices, we choose for the age-efficiency profile an hyperbolic shape in order to have a decreasing with age and time-invariant function (see Fig. 5c):

$$e_i = \frac{T - 1 - i}{T - 1 - \beta i}.$$

We used $\beta = 0.5$ for machinery and equipments, $\beta = 0.75$ for both buildings and housing. This is relatively standard in the literature.[12] The combination of both the mortality of assets and the decrease in efficiency over their lifetime gives the patterns illustrated by Figure 5d.

[12] Same values are used by the US Bureau of Labor Statistics and the Australian Bureau of Statistics for the age-efficiency profile.

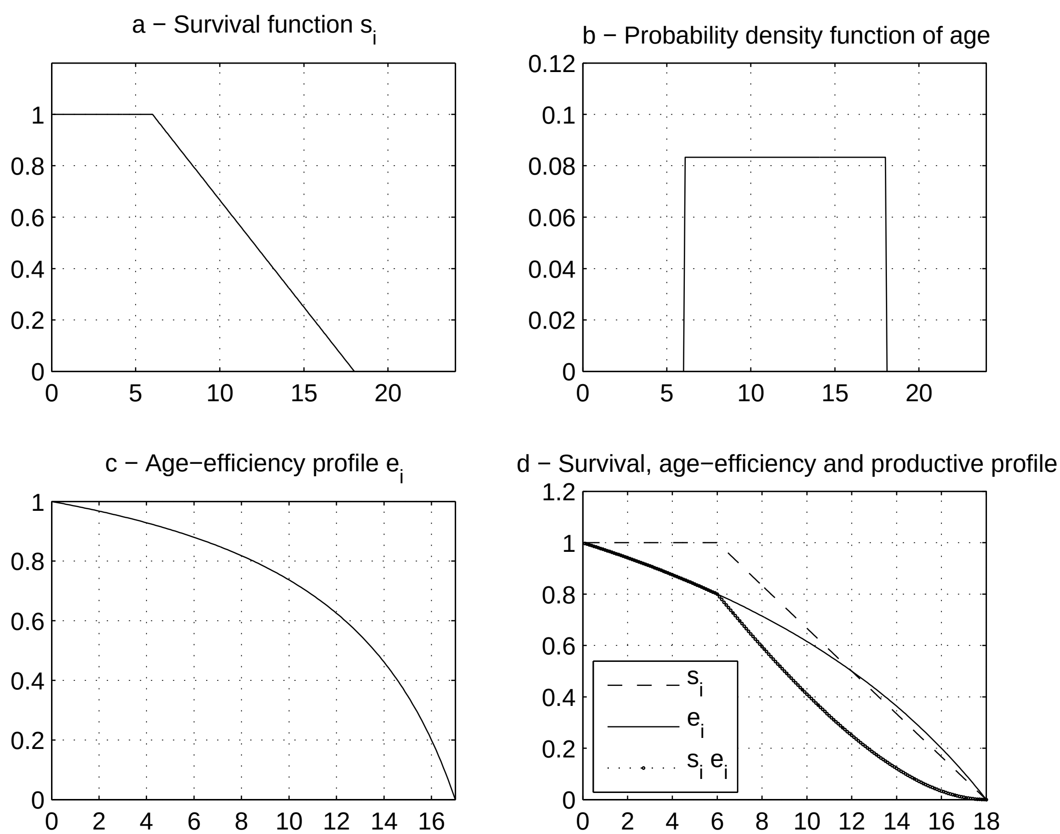

Figure 5: Specific assumptions on mortality and efficiency

A.3 Computation of capital stock for Germany

For Germany, we computed the capital stock data using the method described above and national accounts series at an annual frequency provided by the Bundesbank. The investment data used are in real terms and correspond to the investments in Machinery and Equipments (ME) and investments in Building excluding Housing (BeH).

In order to construct an investment data set for Germany, we first applied the West German growth rate to the total German investment series (both ME and BeH) from 1990 to 1970 backwards.

Second, for getting longer series on investment, we used the historical series on fixed capital stock (gross stock of non-residential structures and gross stock of ME) constructed by Maddison (1993). We backcasted the two total German investment series (ME and BeH) available from 1970 to 2003 with the preceding series (available respectively from 1920 to 1990 and 1880 to 1990) and obtained two total German investment (BeH and ME) series that runs from 1920 to 2003 and 1880 to 2003 respectively.

Concerning the question of calibrating the PIM, we used the same assumptions as for France. The maximal duration of the capital for ME was set to 18 years and 75 years for BeH. These assumptions are not prejudicial since in a document from the OECD (2001), it appears that the average durations for ME and BeH correspond respectively to 12 and 52 years, *i.e.* to the maximal duration of the capital 17.3 years and 77.3 years. As for the depreciation rate, we selected the ones used for France, at an annual frequency 1.5% and 9.5% respectively for BeH and ME. Following these assumptions, we obtained two stocks of productive capital, one associated to investments in BeH and the other to investments in ME, the sum of these two components gives the stock of productive capital for the productive sector in Germany.

A.4 Computation of capital stock for Italy

For Italy, we could not fully compute the capital stock data using the method suggested in the previous subsections since the data set (national accounts series at an annual frequency) are too short and no investment data set is available for Italy in Maddison (1993). The remaining solution consisted therefore in computing stock of capital from a geometric approximation of the mortality law of capital. In order to calculate this geometric approximation, we used the same assumptions as for France.

Since we had at our disposal an investment series for BeH only from 1970 and an investment series for Total Buildings (TB) from 1951, we constructed an investment series for BeH by taking the average share of BeH in TB from 1970 to 2003 and by applying this average share to

TB from 1951 to 1969. We obtained then an investment series for BeH only from 1951 to 2003.

In order to initialize our model, we needed an initial stock of capital $K_{t_0}^P$ (for both BeH and ME). In order to circumvent this concern, we computed this initial stock of capital so that the GDP/capital stock ratio for Italy is identical as the one for France:

$$\frac{K_{t_0}^{P,FR}}{GDP_{t_0}^{FR}} = \frac{K_{t_0}^{P,ITA}}{GDP_{t_0}^{ITA}},$$

with $t_0 = 1950$ and for both investments in BeH and ME.

The GDP figures came from Maddison (1993) ($GDP_{1950}^{ITA} = 164957$ and $GDP_{1950}^{FR} = 220492$ in millions of dollar). Following these assumptions, we obtained two stocks of capital, one associated to investments in BeH and the other to investments in ME, the sum of these two components gives the stock of productive capital for the productive sector in Italy.

B Data appendix

The purpose of this section is to precisely explain how the database used has been built so as to be consistent with the proposed method of estimation.

The productive sector can be identified with the non financial (NFC), financial (FC) and individual (IC) corporations, as defined in the national accounts. It is a distinct concept from the private sector, since the latter is related to the whole economy excluding the public sector. The other sectors of the economy are households, public institutions and NPISH. All available data are taken from the National Statistical Institutes.

Nevertheless, the degree of details varies across countries. In particular, National Accounts in Germany and Italy do not publish the breakdown of macroeconomic indicators (value added, deflators, prices, *etc...*) and production factors (employment, stock of capital, *etc...*) by institutional sector. This breakdown is reconstructed here, based on strong assumptions. It is worthwhile to note that these approximations are necessary in order to keep aggregation consistency.

Before going into the details of the country-specific calculations for France, Germany and Italy, we first present the common calculations performed on the series.

B.1 Common calculations

B.1.1 Households

The series for household employment, N_t^H, is directly available for France, but not for the other countries. An average number of persons employed by French households, $\bar{\nu}_t$ is computed by dividing this series by the number of households H_t^{FRA}:

$$\bar{\nu}_t = \frac{N_t^{H^{\text{FRA}}}}{H_t^{\text{FRA}}}.$$

On a yearly basis, the hypothesis is made that this result also holds for Germany and Italy. Multiplying the average number of persons employed by households by the number of households in each of these countries:

$$N_t^{H^i} = \bar{\nu}_t H_t^i, \quad i \in \{\text{GER,ITA}\},$$

gives an estimate of employment in households' sector for Germany and Italy which is presented in Figure 6a.

This computation requires a long series of annual number of households for each country H_t^i, $i \in \{\text{FRA,GER,ITA}\}$. This is performed by back-dating H_t^i, $i \in \{\text{FRA,GER,ITA}\}$ by means of population series including the number of people between 25 and 64 years. This number stems from the Eurostat website with some official figures as starting points. Still as regards official data, the other sources are the German Federal Ministry of Health and Social Security[13] for Germany and the Mission for Digital Economy of the French Ministry of Finance for Italy and France.[14] Figure 6b shows the calculated number of households for the three countries.

We employ the same method to approximate the households' real value added, Q_t^H. As such data is directly available for France, we used it in order to compute a series of value added per household, and is then multiplied by the number of German and Italian households, H_t^i, which is still computed as above. Figure 6c shows the estimated real value added of households in millions of euros.

B.1.2 Public sector

Employment in the public sector N_t^P is computed by subtracting the employment in the private sector from total employment. The value added of the public sector, Q_t^P, for Germany and Italy are computed with ratios decomposing the gross value added according to its components as a percentage of GDP. These ratios are taken from the Eurostat website. For the sake of simplicity, the indirect taxes net of subsidies are added to the value added of public sector. Figures 7a and 7b plot, respectively, the value added, including indirect taxes net of subsidies, and the employment in the public sector.

[13] http://www.gbe-bund.de/.

[14] http://www.men.minefi.gouv.fr/webmen/informations/tabord/indi/meth/meth.htm.

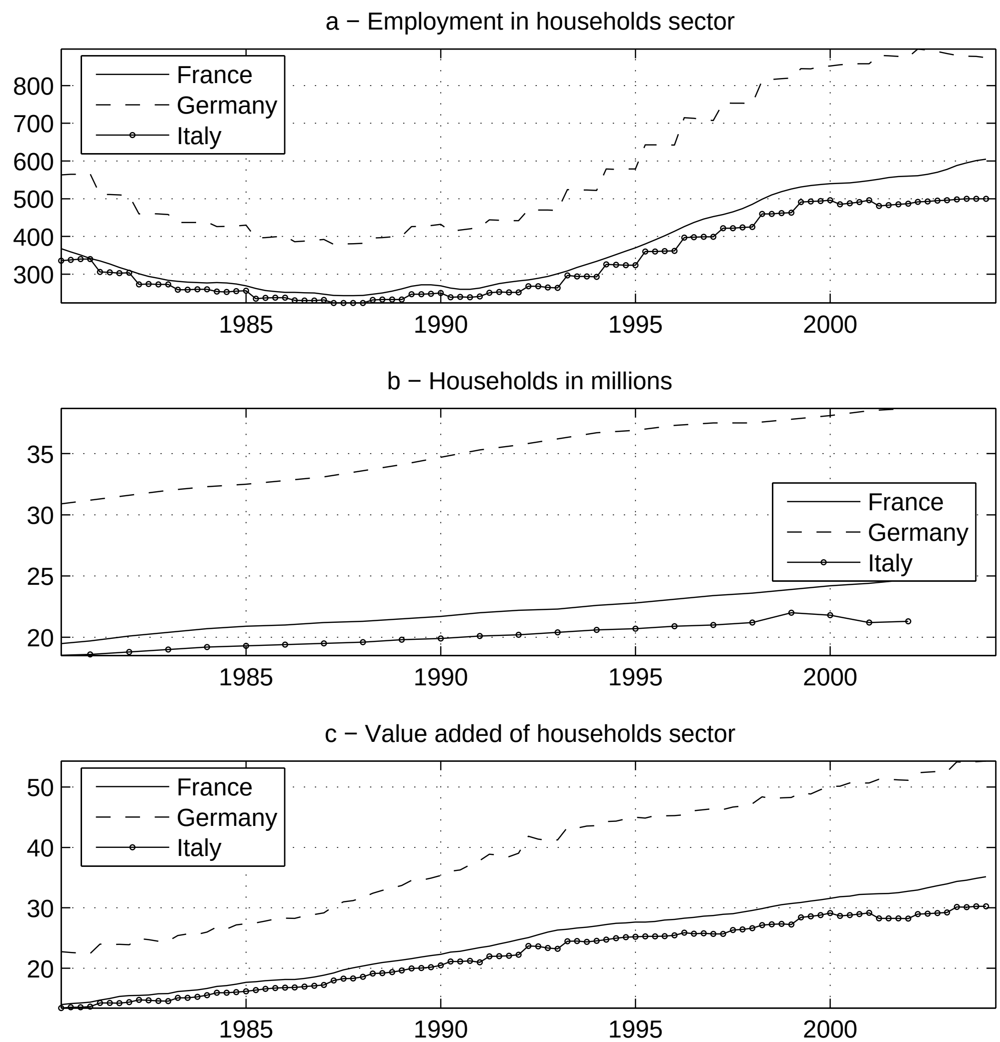

Figure 6: Households sector

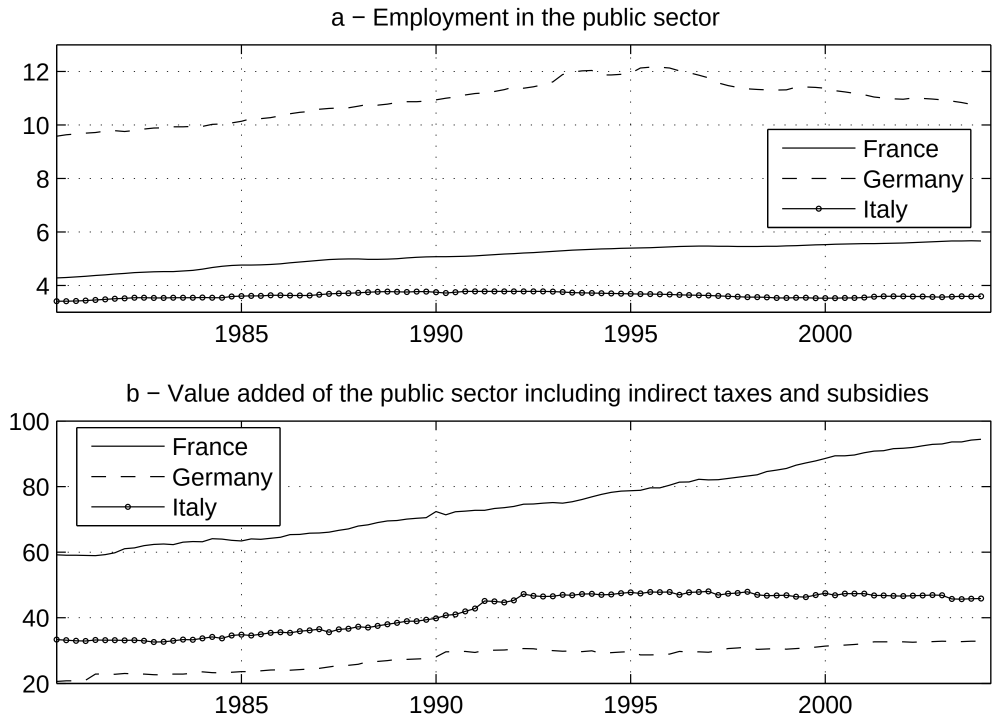

Figure 7: Public sector

B.1.3 Productive sector

The value added, Q_t^B and the employment N_t^B of the productive sector are obtained by subtracting from the total the public, households, NPISH and fictitious unit[15] components, except for Italy for which data on employment in the productive sector are provided by the Banca d'Italia.

B.1.4 Age of the capital stock

The mean age of the stock of productive capital τ_t is calculated by computing an average age, weighted by the part of each investment I_t, discounted at the corresponding scraping rate δ^{mat}, in the current stock of productive capital[16]. The truncation lag T is chosen so that the rest is negligible:

$$\tau_t = \sum_{i=0}^{T} i \frac{(1-\delta^{mat})^i I_{t-i}}{K_t}.$$

[15] Fictitious unit corresponds to the non-classified sector.

[16] More precisely, τ_t is the age of the stock of productive capital associated to investments in ME.

B.1.5 Labour force, participation rate and NAIRU

To keep the data consistent, the computation of the labour force is based on the whole economy employment and unemployment rate series. Participation rate is then calculated with the working age population series. In the medium term, we use the smoothed OECD's measure of time-varying NAIRU (u_t^*) for both Germany and Italy. For France, we used a smoothed version of the NAIRU stemming from the Banque de France's macroeconometric forecasting model for the French economy.[17]

B.2 Country-specific calculations

B.2.1 Germany

Given the lack of data and breaks in time series, mainly due to the reunification, we have performed some simplifications: (i) real value added and employment of German NPISH are supposed to be negligible; (ii) series are back-dated before 1991 using West German data (growth rates); (iii) it turned out that time-series related to employment in the public sector and derived from data in the private sector, presented around 1991 a statistical artefact mainly due to the backdating method. Thus, before 1991, time-series are back-dated with growth rate computed from the difference between employment in the private sector and total employment. After 1991, data are extrapolated by using the growth rate of the ratio $\tilde{N}_t^P = W_t^P/\eta w_t$, where W_t^P is total wages paid by the public sector (available on the Eurostat website), w_t is the compensation per employee for the whole economy and η is a constant. Such a series approximates employment in the public sector.

B.2.2 Italy

The real value added of NPISH is computed with ratios splitting up the gross value added as percentages of GDP. These ratios are taken from the Eurostat website. By assuming that it essentially consists of wages, the employment of NPISH is calculated by dividing the nominal value added by the adjusted compensation per employee.

[17] See Baghli et al. (2004).

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