The Effects of Biased Technological Change on Total Factor Productivity. Empirical Evidence from a Sample of OECD Countries

Cristiano Antonelli, Francesco Quatraro

The Effects of Biased Technological Change on Total Factor Productivity. Empirical Evidence from a Sample of OECD Countries[1].

Cristiano Antonelli
BRICK (Bureau of Research in Innovation, Complexity and Knowledge) Collegio Carlo Alberto & Dipartimento di Economia "S. Cognetti de Martiis" Università di Torino

and

Francesco Quatraro (contact author)
BRICK (Bureau of Research in Innovation, Complexity and Knowledge)
Collegio Carlo Alberto & Dipartimento di Economia "S. Cognetti de Martiis"
Università di Torino

JEL classification codes: O33
Keywords: Total Factor Productivity, Biased Technological Change, International Technology Transfer

[1] We wish to thank the participants to seminars held at the Politecnico of Milan, the Université Lyon Lumière II, the Université Paris Sud-XI and the conference "Knowledge for growth: European strategies in global economy" held in Toulouse, 7th – 9th July 2008, where preliminary versions of this paper have been discussed.

The Effects of Biased Technological Change on Total Factor Productivity. Empirical Evidence from a Sample of OECD Countries.

ABSTRACT.

Technological change is far from neutral. The empirical analysis of the rate and direction of technological change in a significant sample of 12 major OECD countries in the years 1970-2003 confirms the strong bias of new technologies. The paper implements a methodology to identify and disentangle the effects of the direction of technological change upon total factor productivity (TFP) and shows how the introduction of new and biased technologies affects the actual levels of TFP according to the relative local endowments. The empirical evidence confirms that the introduction of biased technologies enhances TFP when its direction matches the characteristics of local factor markets so that locally abundant inputs become more productive. When the direction of technological change favours the intensive use of production factors that are locally scarce, the actual increase of TFP is reduced.

1. Introduction

The historical evidence shows that technological change is strongly biased as it affects asymmetrically the output elasticity of either input such as capital, labour or specific intermediary inputs. Technological change can be capital-intensive, when it favours the usage of capital via the increase of its output elasticity, and hence labour-saving, or labour-intensive, or more specifically skill-intensive, when, on the opposite it favour the use of labour and more specifically skilled labor, when it increases more the output elasticity of labour than that of capital (Robinson, 1938).

A large cliometric evidence suggests that the bias or direction of technological change differs across countries. As Habakkuk (1962) has shown, through the XIX century technological change has been mainly capital-saving in UK and labour- and raw material intensive in the US. Within the same country, different periods of economic growth can be identified by the changes in the direction of technological change (David, 2004). New and convincing evidence has been provided recently about the strong skill-bias of the gales of technological change based upon information and communication technologies introduced in the last decades of the XXI century (Goldin and Katz, 2008). This persistent and renewed evidence about the strong directionality of technological change contrasts the basic methodology elaborated so far to assess its effects.

The conventional methodology for the measurement of total factor productivity (TFP) assumes, in fact, the Hicks neutrality of technological change. Some methodological innovations are requested in order to measure properly the overall effects of technological change on productivity growth, when its directionality is acknowledged. This is all the more necessary when inputs are not equally abundant and hence the slope of the isocost differs from unity. When the introduction of biased technological change (BTC) enables the more intensive use of the more abundant production factors, in fact the consequent change in the slope of isoquants does affect output and hence productivity growth.

As a consequence, countries with different factors' endowments will take advantage of technological innovations that allow for a more intensive use of locally abundant production factors. It follows that countries better able to introduce technologies that are able to matching the local conditions of factor markets should show better productivity performances than countries that have put less effort in shaping technologies according to the relative scarcity of production factors. Standard TFP measurement *à la Solow* does not allow for fully grasping this phenomenon. Such issue becomes even more meaningful when one considers the distinction between innovation and creative adoption (Antonelli, 2006a). Indeed, technologies originated in one country might well be poorly suited to exploit the local conditions of factor markets of other countries. Their productivity-enhancing effects would therefore be much reduced. The effective adoption of those technologies in other countries, featured by different conditions for factor markets, needs for creative efforts aiming at adapting them to the local conditions. A new methodology measuring the effects of BTC on productivity could therefore help investigating the appropriateness of innovation policies based on international technology transfer in follower countries.

In this paper we propose an original methodology able to identify the effect on productivity of such bias and disentangle from it the standard consequences of the shift of the production function. We investigate the direction of technological change for a sample of 12 OECD countries and explore its effects on TFP within a growth accounting framework over the period 1970-2003. We show that: 1) the distinction between biased and neutral technological change is empirically relevant, 2) a specific methodology can identify and disentangle the effects of the rate of technological change from the effects of its bias, 3) the matching between the bias of technological change and the relative factor prices are important triggering factors of the actual change in the efficiency of the production process.

The remainder of the paper is organized as follows. In Section 2 we recall the basic elements about the relationship between changes in the production function and technological innovations. In Section 3 we describe an original methodology to appreciate the specific effects of BTC upon TFP measures. In Section 4 we present the statistical evidence about the actual changes in output elasticities that have been taking place in a large sample of representative countries in the years 1970-2003 and show the results of our methodology to identify and disentangle the effects on TFP of respectively the bias and the shift engendered by technological change. The concluding remarks follow in Section 5.

2. Biased Technological Change and Productivity

Despite the revival of directionality, and its venerable origins, very few attempts may be found in the literature addressing the implications of BTC on the measurement of TFP. This is all the more surprising because Ferguson (1968 and 1969) and Nelson (1973) had already shown that conventional methodologies for the measurement of TFP hold only if technological change is Hicks-neutral and the elasticity of substitution is unitary. This line of reasoning has been mostly neglected, and only recently it has inspired a few empirical studies, aimed to understanding the sources of recent growth in Asian countries relying upon alternative productivity indexes (Felipe and McCombie, 2001; Fisher-Vanden and Jefferson, 2008) and to unveiling the effects of institutional regimes on BTC (Armstrong et al., 2000).

The neglect of the effects of BTC on TFP dates back from the original contribution of Solow (1957). As it is well known Solow allows the change in the output elasticity of capital, as measured by its share on income, and does not account for its effects (Solow, 1957: p. 315, Table 1, col. 4). As a matter of the US case in the years 1909-1949, which Solow analyzed using a Cobb-Douglas based growth accounting methodology, provides clear evidence about the long term stability of factor shares and hence the substantial neutrality of technological change. According to his evidence in the US, the share of property on income did not exhibit significant variations when the starting year is confronted with the end one: in 1909 it was 0.335 and 0.326 in 1949 with a negligible change that might warrant the assumptions about the Hicks neutrality. In the short term, however Solow's data exhibit significant changes: the share of property in income decreased from 0.335 in 1909 to a minimum of 0.322 in 1927 and peaked a maximum of 0.397 in 1932.

The international evidence suggests that the US evidence reported by Solow is quite a special case. Technological change appears to be highly biased in most countries with changing levels of output elasticity and hence high levels of both between and within variance. The recent empirical evidence and the new debate on the relevance of BTC revive the interest in the matter.

A variety of approaches have been considered in the literature on the measure of TFP (Diliberto, Pigliaru, Mura, 2008). Little attention however has been paid to the effects of BTC especially when local factor markets are characterized by significant difference sin the relative abundance of inputs (Van Biesebroeck, 2007). Traditional growth accounting actually keeps fixed the output elasticity of production factors at a given level assuming typically a 0.30 and 0.70 for respectively capital and labor. Translog production functions instead use data for wages and capital service costs that change yearly (Jorgenson and Griliches, 1967). No approach, so far, has identified and appreciated the effects of the changing output elasticity of production factors as a specific form of technological change on TFP.

Within the growth accounting framework, Bernard and Jones (1996) acknowledge that the standard TFP measure is not sufficient in contexts characterized by differences also in factors' elasticities. They develop an index they call "total technology productivity", which accounts for both differences in the traditional "*A*" term and in factors' exponents. However such an index is sensitive to the level of capital intensity used as a benchmark, and anyway it does not account separately for the effect of BTC[2]. Nelson and Pack (1999) have highlighted the limits of conventional TFP growth and stressed the implications in terms of underestimation of the role of capital accumulation in economic growth. David (2004) has provided an outstanding study of the long-term trends of the direction of technological change in the American economic history. The author stresses that standard growth accounting exercises calculating the traditional 'residual' are mistaken in ignoring the effects of factors-deepening, and argues that the

[2] More recently Carlaw and Kosempel (2004) have proposed a decomposition of TFP, by distinguishing between investment-specific technology (IST) and residual-neutral technology (RNT), so as to show that the traditional TFP measure is not sufficient to provide full account of the innovative process.

dynamics of US economic growth of XIX and XX centuries can be featured according to the different directions of technological change in the two periods.

The basic assumption of the theory of production is that a two-way relationship exists between the technology and the production function. All changes in technology affect the production functions well as all changes in the production function reflect the changes in technology. The changes in technology may engender both a shift of the isoquants and a change in their slope. When technological change is neutral the effect consists just in the shift of the map of isoquants towards the origin with no change in their slope. When technological change is biased, the isoquants change both position and slope. Clearly the changes in the values of the output elasticity of basic inputs, as reflected in the changes in the slope of the isoquants, signal the introduction of BTC (see Figure 1). Hence the changes in the levels of TFP can be considered as a reliable indicator of the consequences of technological change only if both the effects on the position (the shift) and on the slope (the bias) of the isoquants are accounted.

>>> INSERT FIGURE 1 ABOUT HERE <<<

Indeed the matching between the direction of technological change and the relative levels of the endowments has powerful effects on the actual efficiency of the production process. It is straightforward to see that the introduction of capital-intensive technologies in a capital abundant country increases output, more than in a labour abundant one (Appendix A illustrates this with a numerical example).

Let us consider the case of a neutral technological change taking place in the capital abundant country Z that leads to the introduction of new superior capital-intensive, but neutral, technology that enhances greatly A, the TFP index calculated with the traditional Solow procedure. Let us now assume that the new superior technology is adopted in the labor-abundant country T where labor-intensive technologies were at work. With respect to the second country the new technology is far from neutral. It should be clear that the increase in the output levels in country T is far lower than in country Z. Adoption is profitable so far as the increase in TFP takes place. The relative advantage of the adopting country however is far lower than that of the innovating country. Actually firms may prefer to delay the adoption of new incremental but biased technologies because of the mismatch between the relative factor prices and their relative output elasticity. The negative effects of the bias can be larger than the small positive effects of the shift of the isoquants. In such a case non-adoption is rational.

The traditional methodology to measure TFP would completely miss these important effects. A new methodology, able to appreciate the change in the output elasticity of production factors, is necessary to identify the effects of the directionality of technological change. The traditional methodology introduced by Solow misses an important dimension of technological change. This failure is all the more relevant when the relative abundance of production factors differs sharply[3]. The introduction of BTC cannot be accounted if the change in the output elasticity is not treated properly. At a closer examination it seems clear that Solow's methodology is able to grasp the effects of a neutral technological change, but not the effects of a biased one. The Solow's methodology does not consider the introduction of BTC as a form of technological change.

Only when the output elasticities are kept constant, in the calculation of the theoretical output, so as to appreciate their change as a specific form of technological change, the ratio of the expected output to the actual historic one can grasp the effects of the introduction of BTC.

The change in the output elasticity of the production factors is by all means the result of the introduction of a specific technological innovation. The standard theory of production in fact tells us that all changes in the production function are the product of the change in technology and *viceversa* all changes in technology do affect the specification of the production function. The introduction of a new and BTC in turn

[3] With respect to the numerical example in Appendix A it is clear in fact that the theoretical output –i.e. the output levels that would be produced if the standard production theory applies- is estimated with the new output elasticities and in fact there would be no discrepancy with respect to the historic output. The residual would be 0 and the Solow's *A* would remain 1. According to the standard methodology to measure TFP and hence the effects of technological change, the introduction of the biased technology would not be appreciated.

engenders, for the given amount of total costs, with no changes in the unit costs of production factors, a clear increase of the output.

3. Methodological Implementation

In order to single out an index for the effects of BTC on TFP, we elaborate upon the so-called "growth accounting" methodology, which draws upon the seminal contribution by Solow (1957) further implemented by Jorgenson (1995) and OECD (2001). In order to confront directly our approach with the seminal contribution by Solow (1957), we shall rely on a Cobb-Douglas production function.

Within this context, this paper applies a specific methodology to identify and disentangle the effects of BTC on productivity growth, so as to separate out the sheer effects of the shift of the production function, from the effects of the changes in isoquants' slope, originally outlined in Antonelli (2003 and 2006b).

When technological change is biased towards the more intensive use of basic inputs that are not evenly abundant, the matching between the output elasticities and the relative factor prices has powerful effects on TFP. Such effects will be positive if the bias favours the more intensive use of production factors that are locally abundant and the effects will be negative if, on the opposite, the direction of technological change will push towards the more intensive use of production factors that are locally scarce (Bailey, Irz, Balcombe, 2004).

The appreciation of such an effect requires a new procedure articulated in two steps: the first allows identifying the effects of the introduction of a technological bias as an intrinsic factor of the actual TFP, the second enables to disentangle the effects of the technological shift from the effects of the technological bias. Let us consider the two steps in turn.

If the expected output is really and consistently calculated assuming that no form of technological change has been taking place, the output elasticity of production factors should not change. Such a 'twice-theoretical output' assumes that the production function has not changed neither with respect to the position of the isoquants nor with respect to their slope. Next we can confront the historic output with the twice-theoretical one: the result should measure the total twin effects of technological change consisting both in the shift of the isoquants and in the changes in their slopes. If the changes in the slope favour the more intensive use of locally abundant and hence cheaper factors, the new methodology would identify a larger residual and hence a larger rate of increase of TFP.

The next step consists in disentangling the effects of the introduction of the technological bias from the effects of the technological shift. To obtain this result it is sufficient to appreciate the Solow theoretical output -as calculated by Solow assuming that output elasticities do change- as the specific measure of the introduction of a technological shift. The difference, between the total twin effect of technological change consisting both in its shift and bias effects, obtained in the previous step, and the Solow-effect, will provide a clear measure of the effects of the introduction of a technological bias.

Let us outline formally the main passages in what follows. The output Y of each country i at time t, is produced from aggregate factor inputs, consisting of capital services (K) and labour services (L), proxied in this analysis by total worked hours. TFP (A) is defined as the Hicks-neutral augmentation of the aggregate inputs. Such a production function has the following specification:

$$Y_{i,t} = A_{i,t} \cdot f(K_{i,t}, L_{i,t}) \tag{1}$$

The standard Cobb-Douglas takes the following format:

$$Y_{i,t} = A \cdot K_{i,t}^{\alpha_{i,t}} \cdot L_{i,t}^{\beta_{i,t}} \tag{2}$$

We can then write TFP as the ratio between the actual observed output and the output that would have been produced through the sheer utilization of production factors:

$$A_{i,t} = \frac{Y_{i,t}}{K_{i,t}^{\alpha_{i,t}} \cdot L_{i,t}^{\beta_{i,t}}} \tag{3}$$

Or in logarithmic form:

$$\ln A_{i,t} = \ln Y_{i,t} - \alpha_{i,t} \ln K_{i,t} - \beta_{i,t} \ln L_{i,t} \quad (4)$$

Where $\alpha_{i,t}$ and $\beta_{i,t}$ represent respectively the output elasticity of capital and labour for each country at each year. It is worth recalling that, according to Solow's formulation, output elasticities of capital and labour are allowed to vary over time. In so doing the effects of their change on productivity are completely neutralized.

Next, following Euler's theorem as in Solow (1957), we assume that output elasticities equal the factors' shares in total income, as we assume perfect competition in both factor and product markets. In view of this, the output elasticity of labour can be expressed as follows:

$$\beta_{i,t} = \frac{w_{i,t} L_{i,t}}{Y_{i,t}} \quad (5)$$

If we also assume constant returns to scale, the output elasticity of capital can be obtained as follows:

$$\alpha_{i,t} = 1 - \beta_{i,t}$$

The measure of *A* obtained in this way, accounts for "any kind of shift in the production function" (Solow, 1957: 312), and it might be considered a rough proxy of technological change (Link, 1987). By means of it Solow intended to propose a way to "segregating shifts of the production function from movements along it". Solow is right if and when technological change is neutral, and/or factors are equally abundant. Instead, the effects of biased technological innovations introduced in countries where factors are not equally abundant, are made up of two elements. Indeed, the discussion conducted in the previous sections suggests that besides the shift effect one should also account for the bias effect, i.e. the direction of technological change.

Once we obtain the TFP accounting for the shift in the production function, we can investigate the impact of the bias effect with a few passages. First of all we obtain a measure of the TFP that accounts for the sum of both the bias and the shift effects (for this reason we call it *total-TFP* or *ATOT*), by assuming output elasticities unchanged with respect to the first year observed. This measure can be therefore written as follows:

$$ATOT_{i,t} = \frac{Y_{i,t}}{K_{i,t}^{\alpha_{i,t=0}} \cdot L_{i,t}^{\beta_{i,t=0}}} \quad (6)$$

The output elasticities for both labour and capital are frozen at time *t=0*, so that at each moment in time the ATOT is equal to the ration between the actual output and the output that would have been obtained by the sheer utilization of production factors, had their elasticities been fixed over time. This index may be also expressed in logarithmic form as follows:

$$\ln ATOT_{i,t} = \ln Y_{i,t} - \alpha_{i,t=0} \ln K_{i,t} - \beta_{i,t=0} \ln L_{i,t} \qquad (7)$$

Next we get the bias effect (*BIAS*) as the difference between *ATOT* and *A*:

$$BIAS_{i,t} = ATOT_{i,t} - A_{i,t} \qquad (8)$$

The index obtained from Equation (11) is straightforward and easy to interpret. Indeed its critical value is zero. When *BIAS* in one country is above (below) zero, then its technological activity is characterized by the right (wrong) directionality, and the slope of isocosts differs from unity.

4. Empirical Analysis

4.1 The Data

The methodological extension proposed in the previous Section clearly relies on the traditional growth accounting approach. The data used for the analysis are mainly drawn from the OECD datasets, and are related to 12 OECD countries, i.e. Austria, Canada, Denmark, Finland, France, Ireland, Italy, Netherlands, Norway, Spain, UK and US. In particular, the data about the GDP, the fixed capital stock and the GDP deflator are provided by the OECD National Accounts series, while the figures concerning the wage rate are drawn from the OECD Economic Outlook. Finally, we took data about employment and total hours worked by the Groningen Growth and Development Centre Total Economy Database.

The GDP, the wage rate and the total fixed capital have been deflated by using the GDP deflator. We then calculated capital services as the two years moving average of capital stock. Following Euler's the output elasticity is calculated as the product of the wage rate and employment level, divided by the GDP. Finally, the productivity indexes have been obtained by introducing total hours worked into equations (3) and (8) instead of employment levels.

These data allow us to derive the BIAS index so as to appreciate the effects of the introduction of BTC on productivity. In what follows we first provide evidence concerning the dynamics of output elasticities, stressing its variation over time and across different countries. Then we will provide the results of the calculations conducted following the methodology presented in Section 3, showing the empirical relevance of BTC in shaping productivity dynamics.

4.2 Directed Technological Change: The Changing Output Elasticity of Labour

In order to show how much pervasive the issue is, it is worth looking at the data concerning the output elasticity of labour. Indeed, should technological change consists just of a shift in the production function, one would observe no change in output elasticities, which clearly reflects the slope of the isoquant. On the other hand, it is clear that according to the Euler theorem the share of revenue of each factor depends exclusively upon its output elasticity (Solow, 1957; Ruttan, 2001). This, actually, makes quite surprising the neglect of the dynamic implications of a change in output elasticities. Table 1 provide clear evidence upon the strong bias of technological change across 12 countries in the time interval of 32 years, from 1970 through 2003. This evidence confirms that the claims about the stability of factor shares (Gollin, 2002) have no empirical foundation even with respect to the US evidence[4]. The international evidence, instead, confirms that the output elasticity of labour indeed varies over time, and is also characterized by remarkable cross country and cross time differences.

>>>INSERT TABLE 1 ABOUT HERE<<<

[4] In this respect, Keay (2000) derived a TFP index using a translog cost function, showing for the US and the Canadian case a significant variance of factors' shares across industries.

The data clearly show a common pattern. Output elasticities indeed are characterized by a stable dynamics across most of the sampled countries along the 1970s with a consistent increase. A discontinuity in the trend takes place since the mid 80s when output elasticity starts declining. On the whole the rate of decrease seems to be more pronounced between mid 1980s and mid 1990s, while it is milder in the late 1990s.

Within this common framework, important differences are found both with respect to the relative levels of elasticities across the sampled countries and to the rate at which they decreased in the last two observed decades. According to the latter, one may roughly distinguish three groups of countries. The first group consists of countries featured by a marked decrease of labour output elasticity. This is particularly evident in the case of Ireland, where one can observe an average percent reduction of about 1,48 per year. This means that in 2003 the value of output elasticity was almost half the value observed in 1971. The same applies also to Spain, Norway and Italy, where labour output elasticity decreased at an average rate of respectively 0.96%, 0.90% and 0.85% per year.

>>>INSERT FIGURE 2 ABOUT HERE<<<

A second group of countries is instead characterized by a softer decline after the late 1970s. Such countries are Austria, Denmark, the UK and the US. In these countries the average rate of decline is around 0.45% per year. In particular, the output elasticity of labour in UK underwent a slight decrease during the 1970s, remained stable during the 1980s and started decreasing again in the 1990s. On the whole, it fell of about 0.52% in the thirty-two years considered. The elasticity for Austria and US diminishes of about 0.45%, while that for Denmark falls of 0.36% per year.

A last group of countries consists of Canada, France and the Netherlands, wherein output elasticities are substantially stable over time. In the first two cases one may observe an average decrease of about -0.2% per year, while in the latter there is an increase of just 0.05%.

Looking at cross-country differences in output elasticity is indeed as much appealing. Besides the generalized trend stressed above, one can note that only in a few countries labour output elasticities stand around 0.5. Out of these, there are Spain and the UK, the starting values of which are respectively 0.757 and 0.636, and Canada and Denmark, where the starting values are respectively 0.549 and 0.568. The rest of the other sampled countries show labour elasticities below 0.5. Ireland and Italy deserve a particular mention in this respect, as labour shares are respectively 0.387 and 0.302 in 2003, i.e. the lowest of the sampled countries.

From this preliminary evidence, it is clear that stability is just one of the possible patterns that output elasticities exhibit over time. Moreover, countries differ both with respect to the levels of relative efficiency of production factors, and to their evolution over time. The empirical evidence confirms that not only the production function is subject to shifts over time, but also to changes in its shape. This is true both diachronically within the same country, and synchronically across different countries.

4.3 Biased Technological Change and TFP

Data show that output elasticities exhibit a great degree of variance both across countries and over time. This evidence is quite clear and yet much overlooked, and hence it makes the analysis of BTC imperative in order to gain a better understanding of the causes and the effects of innovation patterns on productivity growth.

Tables 2 to 4 present the results of our calculations for the countries in the sample. Table 2 reports the evolution of the standard TFP index *à la* Solow. Consistently with the evidence about labour output elasticity, TFP exhibits quite a differentiated dynamics across the sampled countries. Most of the European countries departs from relatively low levels of productivity in 1971 and then follow specific paths. One may note that in this picture Italy shows the lowest initial levels of TFP, and it is characterized by a modest growth trend during the 1970s and the early 1980s. In the following years TFP in Italy was quite stable, and a decreasing trend can be found only in the second half of the 1990s. On the whole, productivity dynamics of Italy are therefore such that it remained the worst off country out of the sampled ones, over the entire observed time span. A number of factors may be responsible of such evidence. The Italian industrial structure has indeed been characterized by a peculiar dynamics, according to which the relative weight of manufacturing sectors has not followed the same path as in the rest of most advanced countries that managed to trigger the development of service industries. In view of this, one would expect innovation strategies to have a poor performance with respect to the introduction of neutral technological change (Quatraro, 2009).

The initial TFP values for Finland are quite similar to the Italian ones, though it experienced a somewhat steeper growth trend during the late 1970s and early 1980s. In 1987 the Finnish TFP began to fall down until 1991, providing and anticipation of the strong recession that the country underwent in the period 1990-1993. Differently from conventional GDP series, TFP in Finland started increasing again in 1990, i.e. in the heart of the recession period. While this may result surprising, it is explained by the dynamics of labour markets during that period, which were mostly hurt by the recession (Dahlman et al., 2006). The data indeed show that both GDP and capital stock fell of about the 10% in the period 1990-1993. This would mean that the productivity of capital remained more or less stable. However, the figures about the total hours worked exhibit a decrease of about the 20% in the same period. This is the reason why the figures about TFP turn out to be increasing during the recession. In the following years the productivity index appeared to be decreasing, as an effect of the recession, and then it started increasing again at the turning of the century.

>>>INSERT TABLE 2 ABOUT HERE<<<

Austria and France seem to be characterized by very similar dynamics, according to which TFP is increasing at an appreciable rate during the 1970s and the first half of the 1980s. Then it falls for a few years and it turns out to increase again along the 1990s. It must be noted however that the French TFP is constantly above that of Austria. Within the group of countries showing relatively low initial levels, Ireland and Netherlands represent two interesting cases. The former indeed exhibit increasing productivity figures until 1987, where it reaches the peak that is well above most of the sampled countries. TFP then remains stable until 1993 and then it starts decreasing at an equally rapid rate, so that at the end of the observed period it is third from last in the productivity rankings. For what concerns Netherlands, despite an evident degree of volatility, the TFP index is characterized by a sound growth trend until the first half of the 1990s, and then it stabilizes. Differently from the previous country, the Netherlands hence gained a good number of positions in the productivity rankings, arriving at the same levels as the UK in 2003.

Two other groups may be identified, each consisting of two countries. The former includes the US and Canada. These two countries are characterized by initial productivity levels that are higher than those observed in the previous group. From a dynamic viewpoint, one may clearly note a few cycles characterizing the two series. First of all, there is an evident reduction of TFP at the end of the 1970s and the beginning of the 1980s. This is the well-known productivity slowdown that worried US economists during the early 1980s (Griliches, 1980). Along the 1980s there is a relative upswing, more marked in Canada than in the US. In both cases the increasing trend of TFP incurs a stop in the early 1990s, though it is less evident for the US, and then started again in the second half of the 1990s, consistently with ICT-driven productivity growth literature (Jorgenson and Lee, 2001).

The last group consists instead of two north-European countries, i.e. Denmark and Norway, which exhibit the highest productivity levels.

The evidence about ATOT is reported in Table 3. It is interesting to note that the index appears to be featured by a clear-cut growth dynamics in almost all of the sampled countries. In particular, it would seem that ATOT follows the same paths as the standard TFP, but magnifying the absolute levels. This is what one should expect, should productivity growth consist not only of a shift component, but also of a bias one. Indeed, particular attention has to be paid to those cases in which the ATOT significantly departs from TFP. This happens in the case of Denmark, Ireland and Norway to quite a great extent. Less marked, but still considerable differences can be found in the case of Italy, the US, the UK and Spain. In the other cases the absolute levels of ATOT are only slightly different from TFP.

>>>INSERT TABLE 3 ABOUT HERE<<<

It is clear that it is the change in output elasticities to determine the different behaviour of the two indexes, and this is the reason why we argue that the effects of BTC on productivity growth deserve appropriate screening. Table 4 provides evidence of the BIAS, combining TFP and ATOT following equation (8). Let us recall that positive values for the BIAS index signal innovation efforts aimed at introducing technological change that allows for better exploitation of idiosyncratic factor markets conditions, while negative values are due to bad matches between technology and factors endowments. It is straightforward that for values of the BIAS equal to zero, the innovative activity is completely characterized by the introduction of neutral technological change.

Let us analyze the empirical results also with the help of Figure 3. It seems that there is a great deal of variety in the sample, both synchronic and diachronic. A particular case is represented by the Netherlands, where the BIAS index is negative all over the observed period. The values are significantly low in the middle of the 1980s and in the middle of the 1990s, signalling the introduction of technologies that were definitely biased towards the more intensive use of locally scarce resources. This is the only case in which the index remains negative for the whole period. In some other cases the BIAS is initially negative along the firs decade, and then it becomes positive in the following years. This applies in particular to Austria, Canada, Denmark, Finland, France and Italy. Out of these countries, the case of Denmark deserves to be mentioned, as therein the BIAS becomes positive in the early 1980s and then starts growing at a very fast rate at the beginning of the 1990s, so that it reaches quite remarkable values. Finland also shows a rapid increase after the early 1990s recession, showing high values since the second half of the 1990s. The evidence for Italy and Austria is characterized by a somewhat marked growth in the second half of the 1990s, while in the cases of Canada and France one can observe a very contained dynamics, so that one can maintain that the BIAS component of technological change in those countries has been quite negligible.

>>>INSERT TABLE 4 ABOUT HERE<<<

>>>INSERT FIGURE 3 ABOUT HERE<<<

The evidence about the US and the UK suggests that the BIAS index is positive since the early observed years, and it increasing over the whole time span, though the levels in the former case are higher than in the latter. Finally, Norway and Ireland are characterized by steady growth dynamics. Norway in particular shows the highest values of the whole sampled countries, and hence appears to be the country that has been better able to combine the advantages of shift and BTC.

To gain better understanding of the relevance of the issue it may be useful to calculate an alternative index that compares ATOT and TFP as follows:

$$SHIFTINT_{i,t} = \frac{ATOT}{AS} = \frac{AS + BIAS}{AS} \qquad (9)$$

This index may be characterized as a proxy of the shift intensity of technological change, and the results of the calculations are reported in table 5 and Figure 4.

This evidence confirms that the matching between the specific direction of technological change and the characteristics of local factor markets has a powerful effect on the evolution of the actual levels of the general efficiency of the production process. Such a relationship is characterized by a significant variance both cross-countries and over time. Moreover, it is worth emphasizing that the new index of BTC has significant implications in terms of country rankings based on productivity. Indeed, countries showing low levels of traditional TFP levels, like Italy, turns out to show better performances when looking at the BIAS index. On the contrary, countries with relatively high levels of TFP, like France, are likely to shift backward in the ranking when looking at the BIAS indexes. In countries like Denmark, Norway, Ireland and Spain technological change exhibits a strong bias in favour of the increase of capital intensity and has a powerful effect on the actual increase of ATOT that is far larger than the TFP measured by the standard Solow indicator. It seems clear that the effects of technological change on economic performance differ substantially from conventional wisdom (Link and Siegel, 2003).

>>>INSERT TABLE 5 ABOUT HERE<<<
>>>INSERT FIGURE 4 ABOUT HERE<<<

The effects of technological change are much deeper and wider than currently acknowledged as they consist both of a shift and a bias effect. The latter has been rarely taken into account. The relation between the two effects can both additive and substitutive. The bias effect can magnify the shift effect as well as reduce it. The interaction between the bias of technological change and the characteristics of local factor markets favours some countries and reduce the actual performances of others. Our empirical evidence suggests that the OCED countries have introduced labour-intensive technological innovations well beyond the relative endowments of labour within their economic systems. The direction of technological change in the OECD countries has been far from neutral and actually too much labour-intensive. The sharp reduction of the ratio of the TFP index calculated with fixed output elasticities at the beginning of the observation period and the Solow's index calculated traditionally with changing output elasticities, in countries like the US in the years 1996-1999 and the constant value below unity of the Netherlands suggests that in these circumstances technological change has taken a direction that is not consistent with the relative supply of capital and labour.

In general, however, as the evidence summarized in table 5 suggests, the direction of technological change matches the relative factor endowments so as to increase the TFP growth.

The inclusion of this dimension into the framework of analysis of the effects of technological change on economic performance seems to open a promising avenue for empirical and theoretical research.

5. Conclusions and Policy Implications

The direction of technological change has powerful effects upon TFP. As such it deserves much more attention than it currently receives. The literature has paid much attention to the shift effects and almost ignored the bias effect. When the bias introduced in the production function by the introduction of a non-neutral technology favours the use of locally abundant production factors, the general efficiency of the production process is enhanced. In some cases the productivity enhancing effects of the bias are larger than the traditional shift effects. The introduction of new technologies that favour the intensive use of locally scarce factors may reduce the potential for the actual increase of efficiency.

The implications of these results are important both for economic analysis and for economic policy. Because the direction of technological change has strong effects, both positive and negative, on the real measure of TFP, it is most important to identify its determinants.

Too much attention has been paid to the determinants of the shifts of the technological frontier while it seems clear that an effort should be made to identify the determinants of the directionality of technological change. The introduction of new biased technologies that are able to take advantage of the local availability of cheap production factors requires distinctive skills, competencies and hence resources that should be identified and appreciated.

The application of this new accounting methodology at less aggregate levels of analysis, and specifically at the regional, sectoral and possibly company level, should help identifying which specific factors play a role in changing the direction of technological change.

The introduction of a bias in technological change can be considered as the result of an effective knowledge infrastructure that displays its effects in terms of technological command only in the long term. As much as the rate of technological change is the endogenous result of economic activity, the direction of the technological change should be treated as the product of both the intentional design of innovators and of the selection of market forces: in both cases the intensive use of locally abundant production factors act as a sorting device that activates learning procedures and stirs dedicated ingenuity and research efforts.

The increase in TFP that stems from the bias of technological change towards the intense usage of locally abundant factors can take place as long as each country has an advanced knowledge infrastructure that makes it possible to command the direction of technological change (Antonelli et al., 2009).

This is even more relevant in countries less able to generate internally technological knowledge that rely upon technological knowledge generated elsewhere. The access to technological knowledge produced elsewhere requires substantial efforts of adaptation to the local factor markets. Technology transfer from other countries can exert much stronger effects when local adopters are able to adapt the foreign technology to the specific conditions of their factor markets. Qualified user-producer interactions even across borders are key to guiding innovation efforts towards the adaptation of new foreign technologies to the conditions of local factor markets. The notion of creative adoption is crucial in this context.

The implications for economic policy are clear. Several empirical and theoretical studies have indeed provided evidence of the relevance of technological change to the process of economic growth. The introduction of new technologies is the outcome of the recombination of different knowledge inputs, both internal and external to economic agents. The access to external sources of knowledge is key to this dynamics, in that it allows economic agents to learn by interacting with other agents, so as to increase their stock of competences. The emphasis on the biased nature of technological change may provide a further qualification of the mechanisms of knowledge transfer, and identify the likely conditions under which it is expected to yield appreciable results.

Most of the literature dealing with the systemic character of innovation processes, like the national-regional innovation system literature, has mainly stressed the role of trust in shaping the interactions within localized context. The quality of the institutional endowment represents in that approach the basic element affecting the likelihood for systemic interactions to emerge and progress. Furthermore, technological relatedness, in terms of similarity of technology fields, is also important in favouring knowledge transfer through the improvement of absorption capacity. While these aspects are important, the evidence provided in this paper suggests that they are not sufficient to guarantee the successful exploitation of external technological knowledge. The idiosyncratic conditions of factor markets are likely to provide constraints that may be difficult to overcome. The exchange of technologies between two economic agents interacting within a conducive institutional endowment, and featured by similar technological capabilities, may turn out not to yield productivity gains if the two agents operate in areas where factor markets are dramatically different. Knowledge transfer strategies should therefore pay appropriate attention to this issue, so as to activate complementary adaptation efforts that would allow to successfully exploiting technologies produced elsewhere. This argument is all the more relevant in the assessment of the prospective stream of investments in environmental-friendly technologies. Even in this case the empirical literature has already showed the key effect of appropriate regulatory regimes (Costantini and Crespi, 2008), but this paper suggests that policymakers should also gain knowledge about the relative endowment of resources so as to properly shape the direction of research efforts. Technology policy should indeed be aimed at favouring the introduction of biased technologies that favour the intensive use of locally abundant factors. The design of technological platforms, conceived as technology infrastructures operating strategically at the interface between the public and the private sectors (Consoli and Patrucco, 2008), which take into account such goals can improve substantially the positive effects of technological change.

6. References

Antonelli, C. (2003), *The economics of innovation new technologies and structural change,* London, Routledge.

Antonelli, C. (2006a), Diffusion as a process of creative adoption, *Journal of Technology Transfer*, 31, 211-226.

Antonelli, C. (2006b), Localized technological change and factor markets: Constraints and inducements to innovation**,** *Structural Change and Economic Dynamics* 17, 224-247.

Antonelli, C., Link, A.N., Metcalfe, J.S. (eds.) (2009), *Technology infrastructure*, Routledge, London.

Armstrong, T.O., Goetz, M.L. and Leppel, K. (2000), Technological change bias in the U.S. investor-owned electric utility industry following potential deregulation, *Economics of Innovation and Technological Change*, 9, 559-572.

Bailey, A., Irz, X., Balcombe, K. (2004), Measuring productivity growth when technological change is biased. A new index and an application to UK agriculture, *Agricultural Economics* 31, 285- 295.

Bernard A. B., Jones C. J. (1996), Comparing apples to oranges: Productivity convergence and measurement across industries and countries, *American Economic Review* 86, 1216-1238.

Carlaw, K. and Kosempel, S. (2004), The sources of total factor productivity growth: Evidence from Canadian data, *Economics of Innovation and Technological Change*, 13, 199-309.

Consoli, D. and Patrucco, P.P. (2008), Innovation platforms and the governance of knowledge: Evidence from Italy and the UK, *Economics of Innovation and Technological Change*, 17, 699-716.

Costantini V. and Crespi F. (2008), Environmental regulation and the export dynamics of energy technologies, *Ecological Economics* 66 (2-3), pp. 447-460.

Dahlman et al. (2006), *Finland as a knowledge economy: Elements of success and lessons learned*, The World Bank, Washington.

David, P. (2004), The tale of two traverses. Innovation and accumulation in the first two centuries of U.S. economic growth, SIEPR Discussion Paper No 03-24, Stanford University.

Diliberto, A., Pigliaru, F., Mura, R. (2008), How to measure the unobservable: A panel technique for the analysis of TFP convergence, *Oxford Economic Papers* 60, 343-368.

Farrell, M.J. (1957), The measurement of productive efficiency, *Journal of the Royal Statistical Society*, Series A, 120, 253-290.

Felipe J. and McCombie J.S.L. (2001), Biased technological change, growth accounting, and the conundrum of the East Asian miracle, *Journal of Comparative Economics* 29, 542-565.

Ferguson C.E. (1968), Neoclassical theory of technical progress and relative factor share, *Southern Economic Journal 34*, 490-504.

Ferguson, C.E. (1969), *Neoclassical theory of production and distribution*, Cambridge University Press, Cambridge.

Fisher-Vanden K. and Jefferson, G.H. (2008), Technology diversity and development: Evidence from China's industrial enterprises, *Journal of Comparative Economics* 36, 658-72.

Goldin, C. and Katz, L. (2008), *The race between education and technology*, Belknap Press for Harvard University Press. Cambridge

Gollin, D. (2002), Getting income shares right, *Journal of Political Economy* 110, 458–74.

Griliches, Z. (1980), R & D and the productivity slowdown, *American Economic Review* 70, 343-48.

Griliches, Z., Mairesse, J. (1998), Production functions: The search for identification, in Strom, S. (ed.), *Econometrics and economic theory in the twentieth century: The Ragnar Frisch symposium*, Cambridge University Press, Cambridge, pp. 169-203.

Jorgenson, D., Griliches, Z. (1967), The explanation of productivity change, *Review of Economic Studies* 34, 249-283.

Habakkuk, H.J. (1962), *American and British technology in the nineteenth century,* Cambridge University Press, Cambridge.

Hicks, J.R. (1932), *The theory of wages*, London, Macmillan.

Jorgenson, D.W. (1995), *Productivity Volume 1: Post-war US economic growth*, Cambridge, MA, MIT Press.

Jorgenson, D.W., Lee, F.C. (eds.) (2001), *Industry-level productivity and international competitiveness between Canada and the United States*, Research Volumes of Industry Canada, Ottawa (http://www.ic.gc.ca/eic/site/eas-aes.nsf/eng/ra01785.html).

Keay, I. (2000), Canadian manufacturers' relative productivity performance, 1907-1990, *Canadian Journal of Economics* 33, 1049-1068.

Link, A.N. (1987), *Technological change and productivity growth*, London, Harwood Academic Publishers.

Link, A.N., Siegel, D.S. (2003), *Technological change and economic performance*, London, Routledge.

Nelson, R.R., (1973), Recent exercises in growth accounting: New understanding or dead end?, *American Economic Review*, 63, 462-468.

Nelson, R.R., Pack, H. (1999), The Asian miracle and modern economic growth theory, *Economic Journal* 109, 416-436.

OECD, (2001), *Measuring productivity. Measurement of aggregate and industry-level productivity growth*, Paris.

Quatraro F. (2009), Innovation, structural change and productivity growth: Evidence from Italian regions, 1980-2003, *Cambridge Journal of Economics*, Advance Access published January 2009, doi:10.1093/cje/ben063.

Robinson, J. (1938), The classification of inventions, Review of Economic Studies 5, 139-142.

Ruttan, V.W., (1997), Induced innovation evolutionary theory and path dependence: Sources of technical change, *Economic Journal* 107, 1520-1529.

Ruttan, V.W. (2001), *Technology growth and development. An induced innovation perspective*, Oxford University Press, Oxford.

Solow R. M. (1957), Technical change and the aggregate production function, *The Review of Economics and Statistics* 39, 312-320.

Van Biesebroeck, J. (2007), Robustness of productivity estimates, *Journal of Industrial Economics* 60, 529-569.

APPENDIX A – A numerical example

For the sake of clarity let us consider a simple numerical example that makes extreme assumptions to grasping the basic point. Let us assume that in a region characterized by an extreme abundance of capital and an extreme scarcity of labor, a firm uses a labor-intensive technology:

$Y_t = K^a L^{1-a}$ where a= 0.25 (A1)

C = rK + wL where r=1 ; w=5 ; C = 100 (A2)

Standard optimization tells us that the firm will be able to produce at best Y=17.

Let us now assume that the firm, at time t+1, is able to introduce a radical technological innovation with a strong capital-intensive bias so as to take advantage of the relative abundance of capital and the relative scarcity of labor in the local factor markets. Specifically let us assume that the new production function will be:

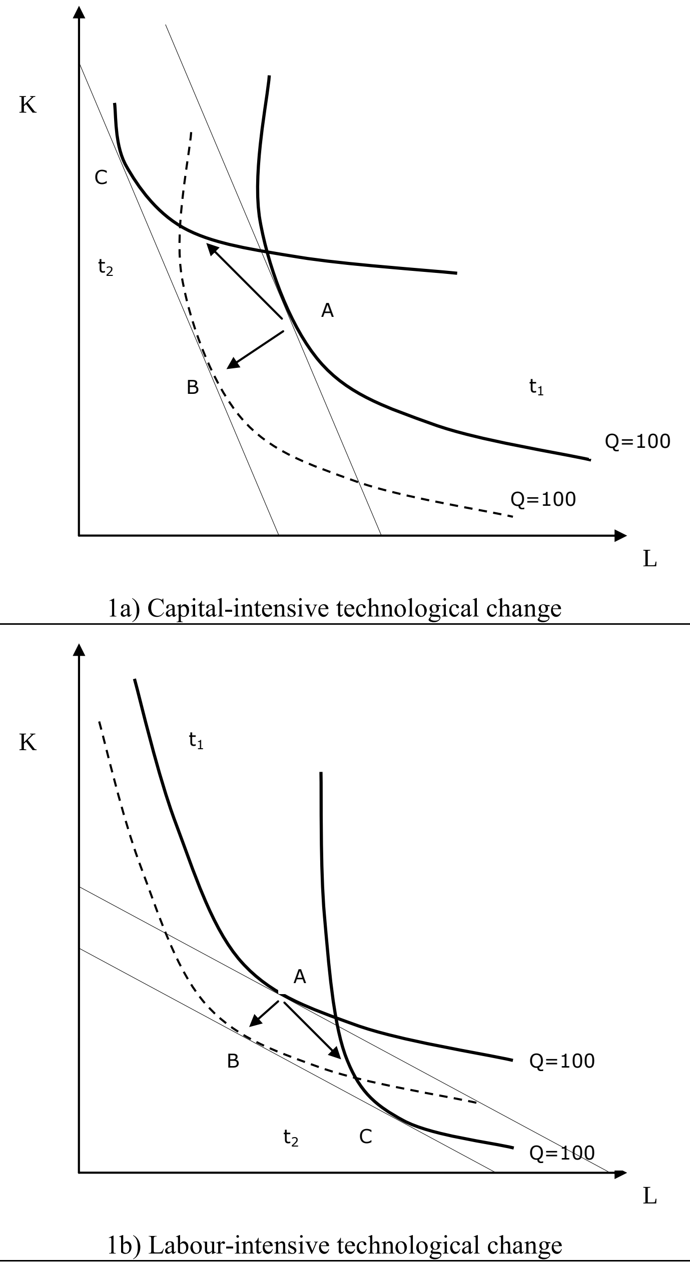
$Y_{t+1} = K^a L^{1-a}$, where a= 0.75 (A3)

C = rK + wL , where r=1 ; w=5 ; C = 100 (A4)

The introduction of a new biased capital-intensive technology, characterized by a much larger output elasticity of capital and hence, assuming constant returns to scale, a much lower output elasticity of labor, with the same budget and the same factor costs, will now enable the output maximizing firm to increase its output to 38. The new technology is 2.2 times as productive as the old one and yet technological change consists just of a bias.

If we reverse the time arrow and we assume that the original technology was capital-intensive with an output elasticity of capital 0.75 and hence a labor elasticity of 0.25 we can easily understand that the introduction of a labor-intensive technology might actually reduce output.

Figure 1 - Biased vs. Neutral Technological Change



1a) Capital-intensive technological change

1b) Labour-intensive technological change

The economy at time t_1 is on the equilibrium point A. At time t_2, the introduction of neutral technological change makes the isoquant shift towards the origin in a parallel way, the new equilibrium point being B. The introduction of biased technological change also causes a change in the slope of isoquant, and the new equilibrium point is now C. The direction of technological change reflects the structure of relative prices. The top diagram shows the case of capital-intensive technological change in contexts characterized by relatively high wage levels. The top diagram shows the case of labour-intensive technological change in contexts characterized by relatively low wage levels (Farrell, 1957).

Figure 2 - Evolution of Labour Output Elasticity

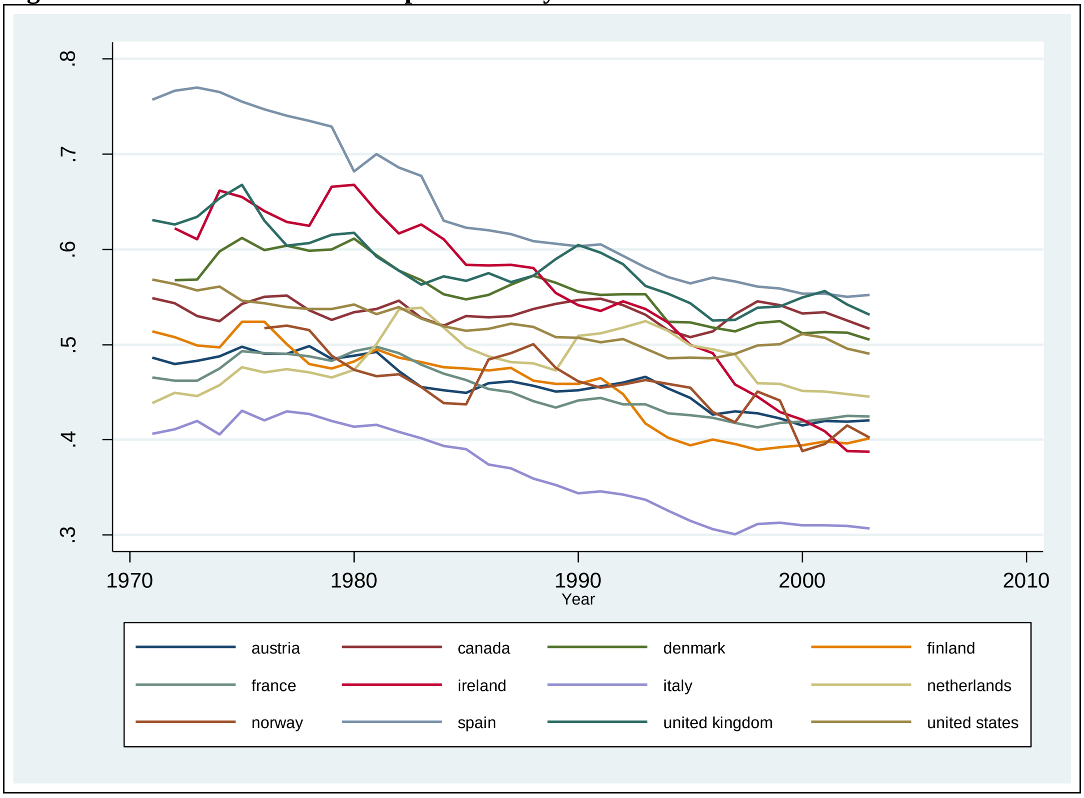


Figure 3 - Evolution of Bias (absolute levels)

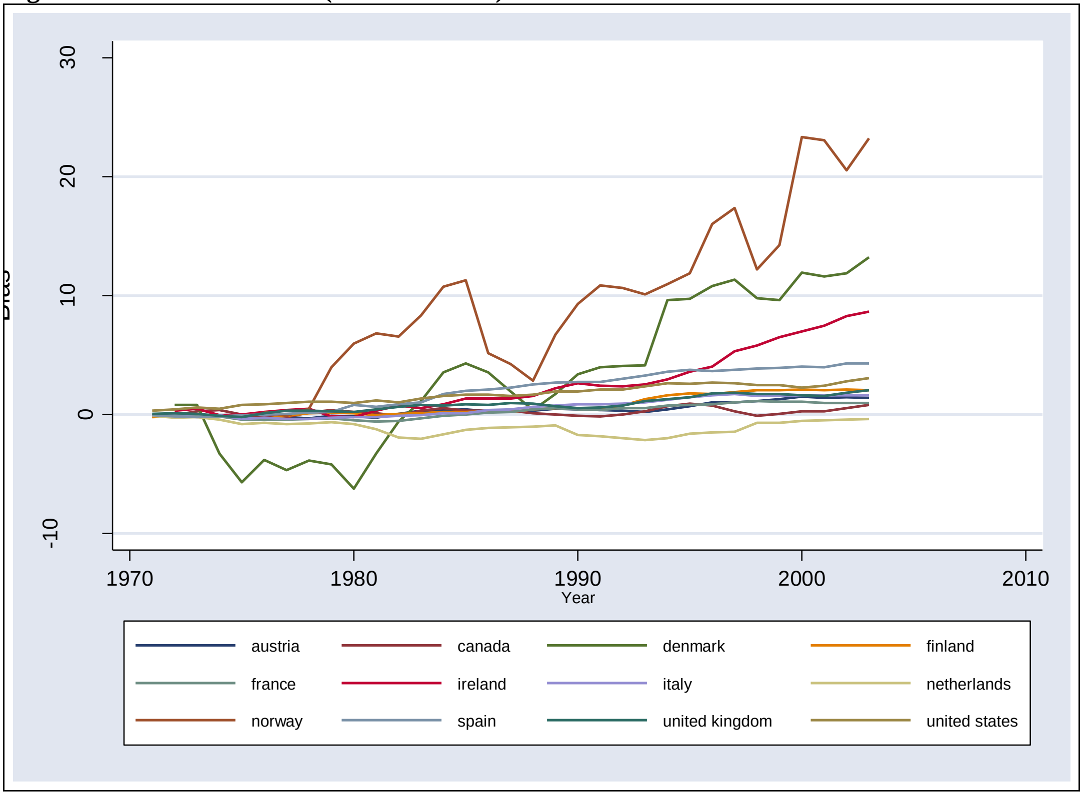


Figure 4 - Evolution of Bias intensity

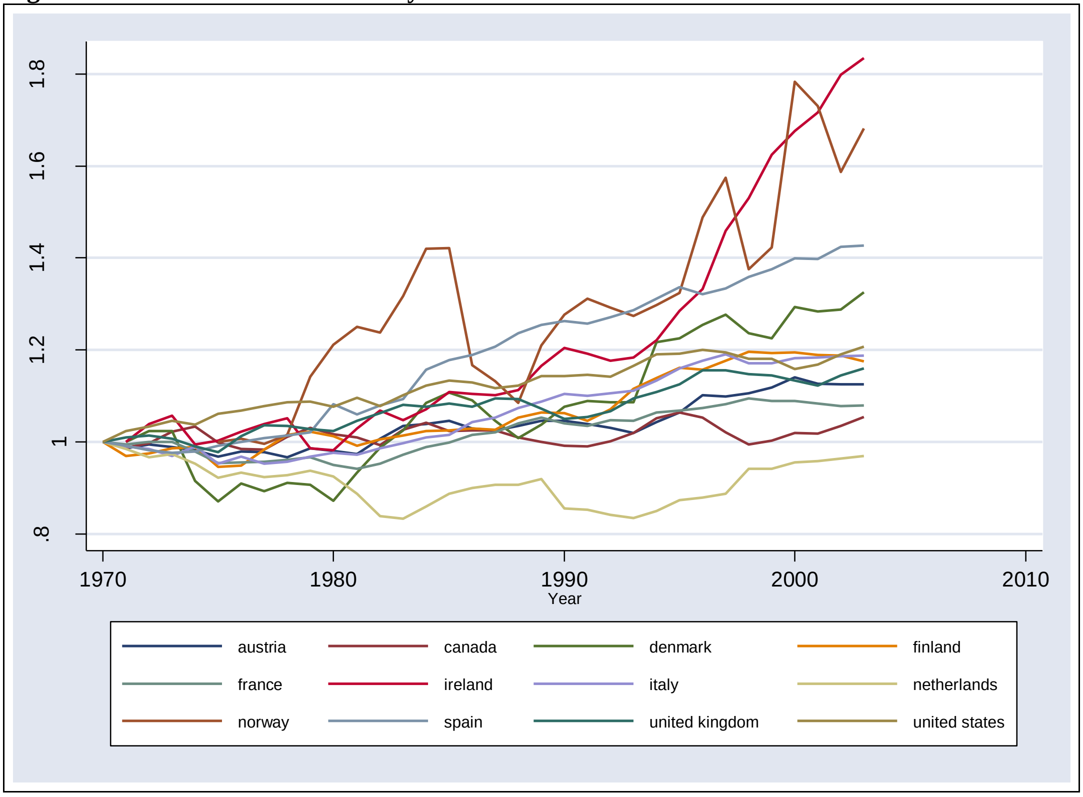


Table 1 - Dynamics of Labour Output Elasticity

	AT	CA	DK	FI	FR	EI	IT	NL	NO	ES	UK	US
1971	0,486	0,549		0,514	0,466		0,406	0,438		0,757	0,631	0,569
1972	0,480	0,544	0,568	0,508	0,462	0,622	0,411	0,450		0,767	0,626	0,563
1973	0,483	0,530	0,568	0,499	0,462	0,610	0,420	0,446		0,770	0,634	0,557
1974	0,487	0,525	0,598	0,497	0,475	0,662	0,405	0,458		0,766	0,654	0,561
1975	0,498	0,543	0,612	0,524	0,493	0,655	0,430	0,476		0,755	0,668	0,546
1976	0,490	0,550	0,599	0,524	0,491	0,640	0,421	0,470	0,517	0,747	0,630	0,543
1977	0,490	0,552	0,604	0,500	0,491	0,629	0,430	0,474	0,520	0,740	0,604	0,540
1978	0,499	0,536	0,599	0,480	0,487	0,625	0,427	0,471	0,515	0,735	0,606	0,537
1979	0,485	0,526	0,600	0,475	0,483	0,666	0,420	0,466	0,488	0,729	0,615	0,537
1980	0,488	0,534	0,611	0,482	0,493	0,668	0,413	0,473	0,474	0,682	0,617	0,542
1981	0,492	0,537	0,594	0,495	0,498	0,640	0,416	0,500	0,467	0,700	0,592	0,532
1982	0,472	0,546	0,578	0,486	0,491	0,617	0,408	0,537	0,469	0,686	0,578	0,540
1983	0,455	0,528	0,567	0,482	0,479	0,626	0,401	0,539	0,455	0,677	0,563	0,527
1984	0,452	0,520	0,553	0,476	0,469	0,611	0,393	0,518	0,438	0,630	0,571	0,519
1985	0,449	0,530	0,548	0,475	0,463	0,584	0,390	0,497	0,437	0,623	0,567	0,514
1986	0,459	0,529	0,552	0,473	0,453	0,583	0,374	0,487	0,484	0,620	0,575	0,516
1987	0,461	0,530	0,563	0,475	0,450	0,584	0,370	0,482	0,491	0,616	0,565	0,522
1988	0,456	0,537	0,572	0,462	0,440	0,581	0,359	0,480	0,500	0,608	0,572	0,519
1989	0,451	0,542	0,565	0,459	0,434	0,554	0,352	0,473	0,476	0,606	0,590	0,508
1990	0,452	0,546	0,555	0,459	0,441	0,542	0,344	0,509	0,462	0,603	0,604	0,507
1991	0,456	0,548	0,552	0,465	0,444	0,535	0,346	0,512	0,455	0,605	0,597	0,502
1992	0,460	0,541	0,553	0,448	0,437	0,546	0,343	0,518	0,458	0,593	0,584	0,506
1993	0,466	0,532	0,553	0,417	0,437	0,537	0,337	0,524	0,462	0,581	0,561	0,496
1994	0,454	0,515	0,524	0,402	0,428	0,523	0,326	0,514	0,459	0,571	0,553	0,486
1995	0,444	0,508	0,523	0,394	0,426	0,499	0,315	0,499	0,455	0,564	0,543	0,486
1996	0,426	0,514	0,518	0,400	0,423	0,491	0,306	0,495	0,429	0,570	0,525	0,486
1997	0,430	0,532	0,514	0,395	0,418	0,458	0,301	0,490	0,419	0,567	0,526	0,490
1998	0,428	0,545	0,523	0,389	0,413	0,445	0,311	0,459	0,450	0,561	0,538	0,499
1999	0,423	0,541	0,524	0,392	0,417	0,429	0,313	0,459	0,441	0,559	0,540	0,500
2000	0,415	0,532	0,512	0,394	0,419	0,421	0,310	0,452	0,388	0,554	0,550	0,511
2001	0,420	0,534	0,513	0,398	0,422	0,409	0,310	0,450	0,395	0,554	0,556	0,507
2002	0,419	0,525	0,512	0,396	0,425	0,388	0,310	0,448	0,415	0,550	0,542	0,496
2003	0,420	0,516	0,505	0,402	0,424	0,387	0,307	0,446	0,402	0,552	0,531	0,490

Table 2 – Dynamics of Total Factor Productivity

	AT	CA	DK	FI	FR	EI	IT	NL	NO	ES	UK	US
1971	7.445	11.873		6.962	7.968		7.068	7.839		7.787	8.190	12.870
1972	7.300	12.008	33.296	7.109	8.073	8.729	7.343	8.469		8.239	8.458	12.705
1973	7.768	11.717	34.472	7.103	8.196	8.600	7.378	8.791		8.492	8.526	12.638
1974	7.993	11.389	39.124	7.049	8.404	9.489	7.131	9.451		8.671	8.558	12.837
1975	8.425	11.671	44.165	7.292	9.000	10.113	7.519	10.080		8.849	8.928	13.106
1976	8.648	12.065	41.812	7.707	9.240	9.749	7.763	10.594	27.211	9.250	8.880	13.101
1977	8.668	12.355	43.828	7.661	9.570	10.020	8.014	10.327	27.996	9.473	8.989	12.681
1978	9.137	12.074	43.786	8.010	9.799	9.971	8.195	10.304	30.189	9.880	9.218	12.303
1979	9.149	11.723	45.224	8.265	9.850	10.219	8.226	10.309	28.041	10.236	9.433	12.177
1980	9.163	11.866	48.708	8.156	9.927	10.891	7.967	10.384	28.132	10.029	9.532	12.559
1981	9.223	11.768	49.468	8.362	10.295	10.609	8.009	11.167	27.256	10.572	9.864	12.579
1982	9.583	12.663	46.457	8.358	10.752	10.843	8.203	12.038	27.561	10.667	9.992	13.045
1983	9.673	12.770	44.819	8.389	11.024	11.667	8.446	12.322	26.176	10.928	10.134	13.061
1984	9.776	13.036	42.137	8.699	11.142	12.220	8.577	11.984	25.628	11.124	10.015	12.705
1985	9.732	13.188	40.110	8.785	11.265	12.567	8.658	11.548	26.779	11.199	10.056	12.713
1986	10.013	13.000	39.477	9.074	11.150	12.751	8.686	11.301	30.969	11.191	10.409	13.003
1987	10.016	12.829	41.993	9.084	10.953	13.426	8.726	11.233	32.093	10.981	10.260	13.363
1988	9.940	12.850	45.714	8.756	10.638	13.674	8.532	11.146	33.343	10.621	10.010	13.488
1989	9.924	12.809	44.867	8.472	10.464	13.319	8.508	11.060	32.056	10.470	10.008	13.383
1990	10.044	13.343	44.343	8.725	10.621	12.924	8.360	12.056	33.586	10.480	10.475	13.765
1991	9.998	14.018	45.282	9.630	10.898	12.739	8.488	12.354	34.889	10.715	11.113	14.223
1992	10.231	14.426	46.920	10.461	11.203	13.347	8.698	12.618	36.495	11.098	11.648	14.578
1993	10.497	14.455	48.190	11.283	11.725	13.866	9.328	13.092	36.858	11.533	11.848	14.126
1994	10.362	13.848	44.234	11.496	11.707	13.343	9.392	13.214	36.724	11.592	11.867	13.724
1995	10.626	14.222	43.196	11.073	11.902	12.729	9.120	12.896	36.704	11.289	11.687	13.543
1996	10.313	14.278	42.554	11.058	11.949	12.232	9.022	12.638	32.932	11.419	11.523	13.515
1997	10.663	14.205	40.987	10.637	12.131	11.597	8.982	12.595	30.252	11.265	11.631	13.573
1998	10.727	14.779	41.511	10.481	11.963	11.018	9.040	11.947	32.554	10.865	11.589	13.727
1999	10.870	14.846	42.690	10.623	11.805	10.412	8.983	11.838	33.795	10.440	11.854	13.777
2000	10.665	14.963	40.555	10.682	11.775	10.345	8.800	11.917	29.829	10.069	12.269	14.142
2001	10.978	15.046	41.074	10.726	11.894	10.481	8.815	12.082	31.635	10.015	12.579	14.427
2002	11.496	14.924	41.306	11.207	12.396	10.420	8.616	12.447	34.997	10.200	12.576	14.793
2003	11.241	14.643	40.687	11.575	12.439	10.378	8.707	12.779	34.085	10.109	12.821	14.836

Table 3 - Dynamics of ATOT

	AT	CA	DK	FI	FR	EI	IT	NL	NO	ES	UK	US
1971	7.342	11.735		6.747	7.930		7.004	7.726		7.727	8.267	13.182
1972	7.264	11.982	34.113	6.936	8.078	9.067	7.229	8.191		8.095	8.572	13.134
1973	7.687	11.981	35.288	7.010	8.195	9.091	7.153	8.558		8.297	8.592	13.221
1974	7.856	11.769	35.822	6.975	8.235	9.437	7.065	9.008		8.494	8.471	13.324
1975	8.154	11.661	38.453	6.898	8.589	10.138	7.169	9.303		8.776	8.728	13.915
1976	8.465	11.888	38.022	7.316	8.831	9.973	7.514	9.888	27.414	9.258	8.991	13.991
1977	8.477	12.144	39.144	7.538	9.156	10.418	7.639	9.544	27.893	9.558	9.318	13.672
1978	8.828	12.215	39.912	8.130	9.420	10.484	7.848	9.566	30.670	10.022	9.541	13.365
1979	9.023	12.087	41.015	8.451	9.529	10.077	7.961	9.661	32.017	10.454	9.691	13.244
1980	8.982	12.061	42.492	8.255	9.434	10.700	7.782	9.606	34.096	10.851	9.765	13.523
1981	8.986	11.883	46.198	8.296	9.701	10.924	7.786	9.917	34.070	11.212	10.318	13.781
1982	9.648	12.577	45.879	8.407	10.239	11.578	8.089	10.106	34.119	11.521	10.616	14.066
1983	10.007	13.112	45.956	8.508	10.726	12.224	8.422	10.264	34.493	11.947	10.948	14.385
1984	10.164	13.579	45.690	8.901	11.015	13.098	8.668	10.299	36.394	12.873	10.788	14.260
1985	10.178	13.494	44.409	9.008	11.250	13.938	8.797	10.242	38.067	13.193	10.897	14.406
1986	10.302	13.331	43.050	9.345	11.318	14.080	9.067	10.165	36.128	13.317	11.213	14.688
1987	10.275	13.146	43.918	9.321	11.183	14.794	9.184	10.189	36.334	13.251	11.231	14.928
1988	10.293	12.978	46.082	9.217	11.067	15.216	9.158	10.110	36.193	13.132	10.944	15.137
1989	10.387	12.807	46.579	9.013	11.021	15.535	9.251	10.164	38.778	13.139	10.730	15.309
1990	10.503	13.239	47.738	9.275	11.049	15.566	9.233	10.317	42.891	13.241	10.998	15.732
1991	10.388	13.875	49.293	10.077	11.277	15.182	9.336	10.530	45.747	13.471	11.725	16.312
1992	10.547	14.450	50.993	11.206	11.729	15.715	9.625	10.625	47.173	14.110	12.433	16.656
1993	10.698	14.737	52.337	12.591	12.261	16.407	10.366	10.925	46.957	14.832	12.972	16.471
1994	10.809	14.573	53.846	13.100	12.456	16.288	10.648	11.227	47.684	15.202	13.153	16.344
1995	11.307	15.133	52.940	12.856	12.714	16.363	10.580	11.273	48.594	15.083	13.160	16.152
1996	11.361	15.038	53.370	12.794	12.824	16.292	10.624	11.113	48.993	15.089	13.313	16.215
1997	11.716	14.504	52.354	12.519	13.134	16.918	10.689	11.171	47.652	15.030	13.448	16.212
1998	11.856	14.698	51.314	12.544	13.098	16.854	10.587	11.252	44.796	14.762	13.302	16.203
1999	12.155	14.885	52.310	12.680	12.861	16.921	10.520	11.142	48.069	14.355	13.573	16.274
2000	12.159	15.258	52.474	12.769	12.830	17.343	10.403	11.391	53.168	14.083	13.902	16.390
2001	12.376	15.311	52.713	12.761	12.893	17.981	10.434	11.586	54.732	14.001	14.117	16.853
2002	12.931	15.456	53.178	13.317	13.355	18.735	10.228	12.006	55.529	14.525	14.400	17.611
2003	12.647	15.447	53.949	13.610	13.431	19.033	10.349	12.393	57.305	14.428	14.881	17.920

Table 4 - Dynamics of BIAS

	AT	CA	DK	FI	FR	EI	IT	NL	NO	ES	UK	US
1971	-0.102	-0.138		-0.215	-0.038		-0.064	-0.113		-0.060	0.077	0.311
1972	-0.036	-0.026	0.817	-0.173	0.004	0.338	-0.114	-0.278		-0.144	0.114	0.429
1973	-0.080	0.263	0.816	-0.094	-0.001	0.491	-0.224	-0.233		-0.194	0.066	0.583
1974	-0.138	0.380	-3.302	-0.074	-0.169	-0.052	-0.065	-0.443		-0.176	-0.087	0.487
1975	-0.270	-0.010	-5.712	-0.394	-0.411	0.026	-0.350	-0.777		-0.074	-0.199	0.809
1976	-0.183	-0.178	-3.789	-0.391	-0.409	0.224	-0.249	-0.706	0.203	0.007	0.111	0.890
1977	-0.191	-0.211	-4.685	-0.123	-0.414	0.398	-0.375	-0.782	-0.103	0.085	0.328	0.990
1978	-0.310	0.141	-3.874	0.120	-0.379	0.513	-0.347	-0.738	0.481	0.142	0.322	1.063
1979	-0.126	0.365	-4.209	0.187	-0.321	-0.142	-0.265	-0.648	3.976	0.219	0.258	1.067
1980	-0.181	0.195	-6.216	0.099	-0.493	-0.192	-0.185	-0.778	5.964	0.822	0.232	0.964
1981	-0.237	0.115	-3.269	-0.066	-0.593	0.315	-0.223	-1.250	6.814	0.641	0.454	1.202
1982	0.065	-0.086	-0.578	0.049	-0.513	0.735	-0.114	-1.932	6.558	0.854	0.624	1.021
1983	0.334	0.341	1.137	0.119	-0.297	0.556	-0.024	-2.058	8.317	1.019	0.814	1.324
1984	0.389	0.543	3.553	0.202	-0.128	0.877	0.091	-1.685	10.765	1.748	0.773	1.555
1985	0.445	0.306	4.299	0.223	-0.015	1.372	0.139	-1.305	11.288	1.994	0.841	1.694
1986	0.289	0.331	3.573	0.271	0.168	1.329	0.381	-1.136	5.160	2.126	0.804	1.685
1987	0.259	0.317	1.925	0.237	0.230	1.368	0.458	-1.044	4.241	2.270	0.971	1.566
1988	0.353	0.128	0.367	0.461	0.429	1.542	0.626	-1.035	2.850	2.511	0.934	1.649
1989	0.463	-0.002	1.712	0.540	0.557	2.215	0.742	-0.895	6.722	2.668	0.721	1.926
1990	0.459	-0.103	3.395	0.550	0.428	2.642	0.873	-1.739	9.304	2.762	0.523	1.967
1991	0.390	-0.143	4.011	0.447	0.379	2.443	0.848	-1.823	10.859	2.756	0.611	2.089
1992	0.315	0.024	4.073	0.745	0.526	2.369	0.927	-1.994	10.678	3.012	0.784	2.079
1993	0.201	0.282	4.147	1.308	0.537	2.540	1.038	-2.167	10.099	3.299	1.123	2.345
1994	0.446	0.725	9.611	1.603	0.749	2.945	1.256	-1.987	10.960	3.610	1.286	2.619
1995	0.682	0.911	9.745	1.782	0.812	3.633	1.460	-1.623	11.890	3.794	1.473	2.609
1996	1.049	0.761	10.816	1.736	0.875	4.061	1.601	-1.525	16.061	3.670	1.790	2.700
1997	1.053	0.298	11.366	1.882	1.003	5.322	1.708	-1.425	17.400	3.764	1.817	2.639
1998	1.128	-0.081	9.803	2.063	1.135	5.836	1.547	-0.695	12.242	3.896	1.713	2.475
1999	1.285	0.039	9.620	2.057	1.056	6.509	1.538	-0.696	14.274	3.915	1.720	2.497
2000	1.494	0.295	11.919	2.087	1.055	6.998	1.604	-0.526	23.339	4.015	1.632	2.248
2001	1.397	0.265	11.639	2.034	0.999	7.500	1.620	-0.496	23.097	3.986	1.538	2.426
2002	1.435	0.532	11.872	2.110	0.959	8.314	1.612	-0.441	20.532	4.325	1.824	2.818
2003	1.406	0.804	13.262	2.034	0.992	8.655	1.642	-0.386	23.220	4.318	2.060	3.084

Table 5 - Dynamics of Shift intensity

	AT	CA	DK	FI	FR	EI	IT	NL	NO	ES	UK	US
1970	1.000	1.000		1.000	1.000		1.000	1.000		1.000	1.000	1.000
1971	0.986	0.988	1.000	0.969	0.995	1.000	0.991	0.986		0.992	1.009	1.024
1972	0.995	0.998	1.025	0.976	1.001	1.039	0.985	0.967		0.982	1.013	1.034
1973	0.990	1.022	1.024	0.987	1.000	1.057	0.970	0.974		0.977	1.008	1.046
1974	0.983	1.033	0.916	0.990	0.980	0.994	0.991	0.953		0.980	0.990	1.038
1975	0.968	0.999	0.871	0.946	0.954	1.003	0.953	0.923	1.000	0.992	0.978	1.062
1976	0.979	0.985	0.909	0.949	0.956	1.023	0.968	0.933	1.007	1.001	1.013	1.068
1977	0.978	0.983	0.893	0.984	0.957	1.040	0.953	0.924	0.996	1.009	1.037	1.078
1978	0.966	1.012	0.912	1.015	0.961	1.051	0.958	0.928	1.016	1.014	1.035	1.086
1979	0.986	1.031	0.907	1.023	0.967	0.986	0.968	0.937	1.142	1.021	1.027	1.088
1980	0.980	1.016	0.872	1.012	0.950	0.982	0.977	0.925	1.212	1.082	1.024	1.077
1981	0.974	1.010	0.934	0.992	0.942	1.030	0.972	0.888	1.250	1.061	1.046	1.096
1982	1.007	0.993	0.988	1.006	0.952	1.068	0.986	0.839	1.238	1.080	1.062	1.078
1983	1.035	1.027	1.025	1.014	0.973	1.048	0.997	0.833	1.318	1.093	1.080	1.101
1984	1.040	1.042	1.084	1.023	0.989	1.072	1.011	0.859	1.420	1.157	1.077	1.122
1985	1.046	1.023	1.107	1.025	0.999	1.109	1.016	0.887	1.422	1.178	1.084	1.133
1986	1.029	1.025	1.091	1.030	1.015	1.104	1.044	0.900	1.167	1.190	1.077	1.130
1987	1.026	1.025	1.046	1.026	1.021	1.102	1.052	0.907	1.132	1.207	1.095	1.117
1988	1.036	1.010	1.008	1.053	1.040	1.113	1.073	0.907	1.085	1.236	1.093	1.122
1989	1.047	1.000	1.038	1.064	1.053	1.166	1.087	0.919	1.210	1.255	1.072	1.144
1990	1.046	0.992	1.077	1.063	1.040	1.204	1.104	0.856	1.277	1.264	1.050	1.143
1991	1.039	0.990	1.089	1.046	1.035	1.192	1.100	0.852	1.311	1.257	1.055	1.147
1992	1.031	1.002	1.087	1.071	1.047	1.177	1.107	0.842	1.293	1.271	1.067	1.143
1993	1.019	1.020	1.086	1.116	1.046	1.183	1.111	0.834	1.274	1.286	1.095	1.166
1994	1.043	1.052	1.217	1.139	1.064	1.221	1.134	0.850	1.298	1.311	1.108	1.191
1995	1.064	1.064	1.226	1.161	1.068	1.285	1.160	0.874	1.324	1.336	1.126	1.193
1996	1.102	1.053	1.254	1.157	1.073	1.332	1.177	0.879	1.488	1.321	1.155	1.200
1997	1.099	1.021	1.277	1.177	1.083	1.459	1.190	0.887	1.575	1.334	1.156	1.194
1998	1.105	0.995	1.236	1.197	1.095	1.530	1.171	0.942	1.376	1.359	1.148	1.180
1999	1.118	1.003	1.225	1.194	1.089	1.625	1.171	0.941	1.422	1.375	1.145	1.181
2000	1.140	1.020	1.294	1.195	1.090	1.676	1.182	0.956	1.782	1.399	1.133	1.159
2001	1.127	1.018	1.283	1.190	1.084	1.716	1.184	0.959	1.730	1.398	1.122	1.168
2002	1.125	1.036	1.287	1.188	1.077	1.798	1.187	0.965	1.587	1.424	1.145	1.191
2003	1.125	1.055	1.326	1.176	1.080	1.834	1.189	0.970	1.681	1.427	1.161	1.208