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TFP, Welfare and Innovation: The Implications for an Index of Innovation

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TFP, WELFARE AND INNOVATION: THE IMPLICATIONS FOR AN INDEX OF INNOVATION

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Abstract: This paper argues that the output of innovation is best measured by welfare gains rather than improvements in productive efficiency. A new welfare based index of the impact of innovation is proposed that plays down domestic exports but emphasises innovation imported via final products. It is shown that the contribution to overall welfare growth of such imported innovation, although differing across countries and industries, is significant, and it is thus further argued that it should be reflected in an innovation index.

EXECUTIVE SUMMARY

1. This work is a contribution to a NESTA led project on the construction of a new Index of Innovation. It has already been agreed that the index will be a measure of investments in innovative activity. It is argued here that a necessary preliminary to measuring such investments is to agree upon the outputs of innovative activity.
2. Most prior analysis of innovation, in economics at least, has concentrated upon changes in productive efficiency, especially the rate of growth of total factor productivity (GTFP), as measures of the output of innovation.
3. Here it is argued that changes in economic welfare would be a better indicator of the output of innovation. Consideration of the means of measuring such changes leads to the definition of a new measure, the welfare innovation rate (or i(t)), that reflects the contributions of innovation to changes in economic welfare rather than productive efficiency.
4. The main characteristic of the new measure is that it considers that exported production does not (directly) generate welfare in the domestic economy whereas imports do generate such welfare. Welfare gains arising from innovation thus come from two sources, from the contribution of innovation to the efficiency of domestic production consumed at home and from innovation overseas that makes imported final goods better or cheaper.
5. Calculations at the macro economic level indicate that in the UK and in seven comparator countries, the mean estimated values of i(t) and GTFP over the period from 1988 – 2004 are little different from each other, although the former is less volatile.
6. However, also at the level of the macro economy, estimates have been made of the contribution of imported innovation and innovation in non exported domestic production to the new welfare growth index. For the UK it is found that imported innovation on average contributed 16.5% of the total growth in welfare from innovation. The contribution of imported innovation to the growth in welfare from innovation in comparator countries varies from a high of 21.% % for Canada down to about 2% for the US and Japan with France Germany and Italy at about 6%.

7. The exercise has been repeated at the industry level for manufacturing as a whole and for ten sectors within manufacturing. Here much greater differences than at the macro level are found between i(t) and GTFP especially at the lower level of aggregation. In addition there are big differences across industries in the relative contribution of imported innovation to the total growth in welfare from innovation.
8. Although the exercise is in the nature of accounting rather than explanation, it is concluded that production based and welfare based approaches do yield different answers to basic question, especially as the analysis becomes disaggregated. It also argued that welfare based approaches are to be preferred. The main lessons for index construction are that (i) the output of innovation needs careful consideration and (ii) imported and exported benefits are an important element to consider.
9. Further work relating to checking, extensions, implications and policy is specified and costed.

TFP, WELFARE AND INNOVATION: THE IMPLICATIONS FOR AN INDEX OF INNOVATION

1. Introduction

In general terms the objective of an innovation index is to measure the level of innovative activity. It is already agreed that the approach to be taken in the NESTA exercise will concentrate upon investments in innovative activity, although until innovative activity or the output of innovative activity is defined the investments cannot actually be specified. A crucial first step in devising an index thus concerns decisions as to the measure of the output of innovative activity.

Innovation may impact in many areas, but most innovation studies and attempts to measure the rate of innovation in economics take a production orientated view and explore how innovation impacts upon productive efficiency. This is out of line with most of economics where the main concern is with impacts upon economic welfare, and production and welfare do not necessarily correspond. The purpose here is to attempt to take a welfare orientated rather than production orientated viewpoint of the impact of innovation and as result gain some new insights in to both the impacts and the drivers of innovation[1]. Although rather parochial the analysis is restricted to welfare in individual economies as is most of the extant literature.

2. Definitions

[1] Oulton (2004) has also argued that production and welfare orientated views will yield different results and contends that while Gross Domestic Product is satisfactory as a measure of output, it is outclassed as a measure of welfare by Net Domestic Product as defined by Weitzman (1976) - nominal net domestic product (consumption plus net investment) deflated by the price index for consumption. In this paper however in contrast to the work of Oulton (2004) and Weitzman (1976) the main issue is to do with imports and exports as opposed to the correct means of deflation of investment spending.

Although they are standard it is worth stating some definitions of some macro economic concepts that are employed below.

National income (NI) is defined as income earned by residents from current production of goods and services in the economy and

NI = Employees compensation plus income of the self employed (Ω) plus
corporate profits (Π) plus
rents and interest, (Γ)

Net National Product (NNP) at market prices is given thus

NNP = NI plus
indirect taxes (T) less
subsidies (S)

Gross National Product (GNP) is given by

GNP = NNP plus
Capital depreciation (D)

While Gross Domestic Product (GDP) is given by

GDP = GNP plus
net payments of income abroad (PA) less
net receipts of income from abroad (RA)

Note that Gross National Product refers to output produced by productive factors owned by permanent residents of a country (wherever those factors may be located) while Gross Domestic Product refers to output produced by productive factors located in a country, regardless of their owners' nationalities. If welfare is to be discussed it is important to clarify whether the concern is for the welfare of permanent residents of a country no matter where the factors they own are employed or the welfare of the owners of productive factors used in the domestic economy whatever their nationality.

The difference comes down to whether net payments of income abroad (PA) less net receipts of income from abroad (RA) should or should not be taken into account when discussing welfare. Partly in order to avoid the complication of trying to measure and model these two concepts, and partly to keep in line with the majority of existing literature on productivity measurement (with certain comparability advantages) it has been decided to concentrate here upon the welfare of the owners of productive factors employed in a country, regardless of their owners nationality. This is equivalent to choosing GDP as opposed to GNP as the variable of interest. From this point on we thus include all owners of productive factors employed in a country within the term "domestic residents".

By definition, gross domestic product equals total expenditure on goods and services produced by domestic residents. Most importantly for what follows, GDP does not measure total spending by domestic residents. GDP is instead made up of (home) consumption[2] (P_cC), investment or additions to the capital stock (P_iI) and government spending (P_gG) (note that consumption, investment and government spending encompass purchases of both domestically produced and imported products and services) plus exports (P_xX) but minus imports (P_mM), with all prices expressed in the domestic currency i.e.

(1) $$GDP = P_cC + P_iI + P_gG + P_xX - P_mM$$

where P_mM equals $\Sigma_j P_m^j(t)M^j(t)$ i.e. the sum of the value of imports from all other countries j, with P_m^j being the price of imports from country j converted to sterling at the current exchange rate.

From above it also the case that

(2) $$GDP = \Omega + \Pi + \Gamma + T - S + D + PA - RA$$

Finally using the output method GDP can be defined/calculated as the value of the output of goods and services produced in the economy in a given period. In such

[2] Where P_c is the price and C is the quantity, a convention used for other aggregates

circumstance let Q be the number of units of output produced in the economy and P_q the price at which they are sold, let Z and P_z be the quantity and price of raw material and intermediate inputs used in their production[3], then GDP is given by the sum of value added produced i.e.

(3) $GDP = P_qQ - P_zZ$

From (1), (2) or (3) subtraction of capital depreciation (D) gives net domestic product, which is the level of output that is available after covering the cost or replacing worn out capital.

3 Welfare

It is common in much of the (especially neo classical) economics literature to study the impact of innovative activity by calculating the growth of total factor productivity (GTFP). GTFP measures either the increase in output for given factor inputs that innovation will induce (or allow), or alternatively the reduction in unit cost that innovation will induce for given factor prices[4].

The determinants of GTFP will then indicate what factors it is necessary to measure in order to build an index of investments in innovation. Past analysis has suggested the use of indicators such as research and development spending, imports of improved capital equipment, embodied skills in the labour force or just manna from heaven.

Typical of analysis that has been undertaken to measure GTFP is the impressive body of work to be found as part of the EUKLEMS Project (see www.euklems.net) where international aggregate and industry level comparisons over a long time period have been pursued. At the macro level, in common with by far the larger part of the literature, this study has taken GDP as the appropriate indicator of output, while at the industry level value added has been used, both measured via the output method as in (3) above.

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[3] This includes imported raw material and intermediate inputs.

[4] Battisti et. al. (2009), argue that TFP multiplied by ROCE, measuring the contribution of innovation to firm profitability, may be a preferred indicator if innovation is defined as "the successful exploitation of new ideas".

The essential insight that comes from taking a welfare view point arises from the consideration of the welfare contribution of innovation in the production of imports and exports. Recalling that our interest is in the welfare of the owners of productive factors employed in a country, regardless of their owners' nationality, the issue may be addressed from several different starting points.

1. Sometimes welfare is defined as the sum (over all goods and services) of producer and consumer surpluses[5] generated in an economy. More precisely, for the UK, this will be profits earned by capital goods used in production in the UK plus the utility derived from consumption by the owners of, and recipients of income from, factors employed in UK production (labour and capital) over and above the cost of goods consumed. Consumer surplus enjoyed by recipients of income from other countries should not be included i.e. consumer surplus enjoyed by those who purchase exports from the UK. Equivalently consumer surplus enjoyed by recipients of UK incomes purchasing imports should be included. Welfare will thus be equal to profits earned in the UK plus the share of total consumer surplus generated by production in the UK that is enjoyed in the UK, less that which is exported plus any consumer surplus arising from imports. Although measuring producer and consumer surpluses is not however particularly practical, this approach does suggest that in considering welfare that exports and imports require careful treatment.

2. A second approach is via what has become known as the "Bergson-Samuelson" social welfare function (SWF). In this case welfare in an economy is assumed to be such that

$$W = W(U^1, U^2, .., U^H)$$

so that "society's" welfare denoted, W, is merely a function of the utilities of its constituent members, U^h, h = 1, 2, .., H, where H are the number of households in society. Assuming the household utilities are derived from consumption, this

[5] For detail see, for example, a standard text such as Besanko and Braeutigam (2008), pp 159 – 165.

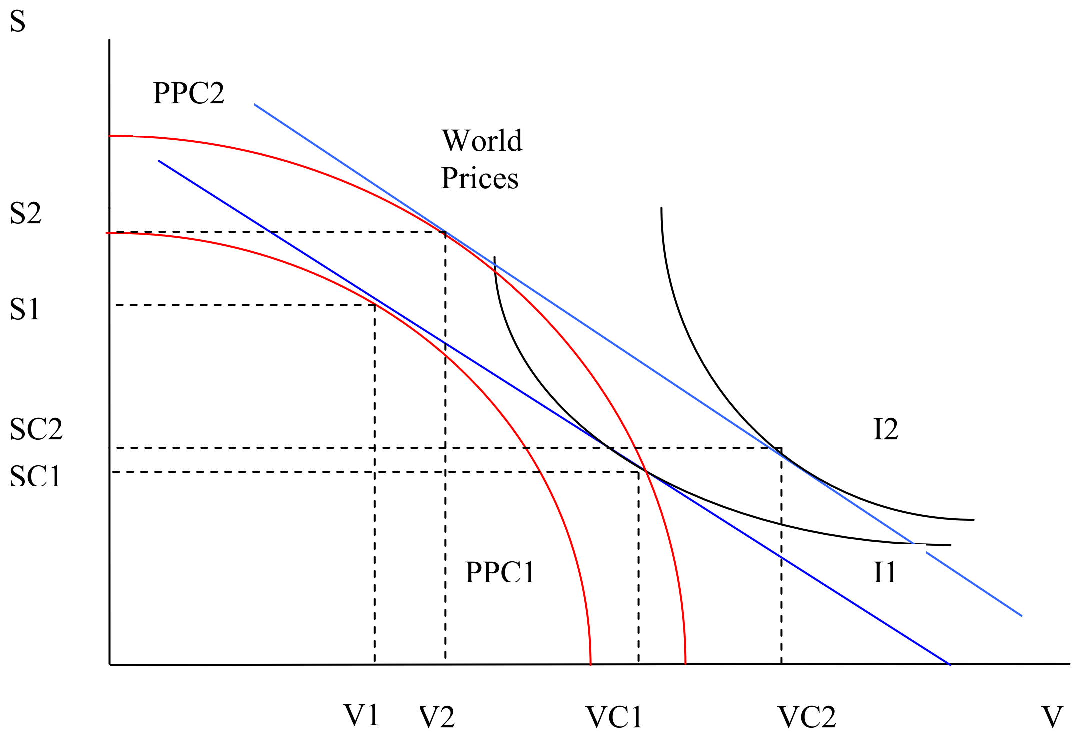
would suggest that utility of the owners of productive factors employed in a country would relate to their consumption and not production. As exports are not consumed by such persons whereas non exported UK production and imports are, then welfare will be related to the latter two rather than the former. Again, although not particularly practical some special consideration of exports and imports is suggested by this approach.

3 Building upon the concept of the social welfare function one may define a community indifference curve that plots combinations of consumption patterns that provide points of equal social welfare for given inputs. Assume an economy with two goods S and V that can be produced either at home or imported from overseas. In Figure 1 (a standard text book representation usually used to show the advantages of trade, see for example Pindyck and Rubinfield, 1998), let there be an initial production possibility curve (PPC1) that plots combinations of S and V that can be produced from given factor endowments.

Relative world prices at which the two goods can be traded are given by the sloping line so marked. Allow I1 to be the initial community indifference curve. Assuming utility and profit maximization, output at home will then equal (S1, V1) and consumption at home will be (SC1, VC1) with exports of S being S1 – SC1 and imports of V being VC1 – V1. Note that welfare is generated by home production minus exports plus imports.

Allow the PPC curve to shift to PPC2, relative world prices remaining constant. In the new equilibrium output at home will then equal (S2, V2) and consumption at home will be (SC2, VC2) with exports of S being S2 – SC2 and imports of V being VC2 – V2. Welfare in the new equilibrium is given by the CIC curve I2.

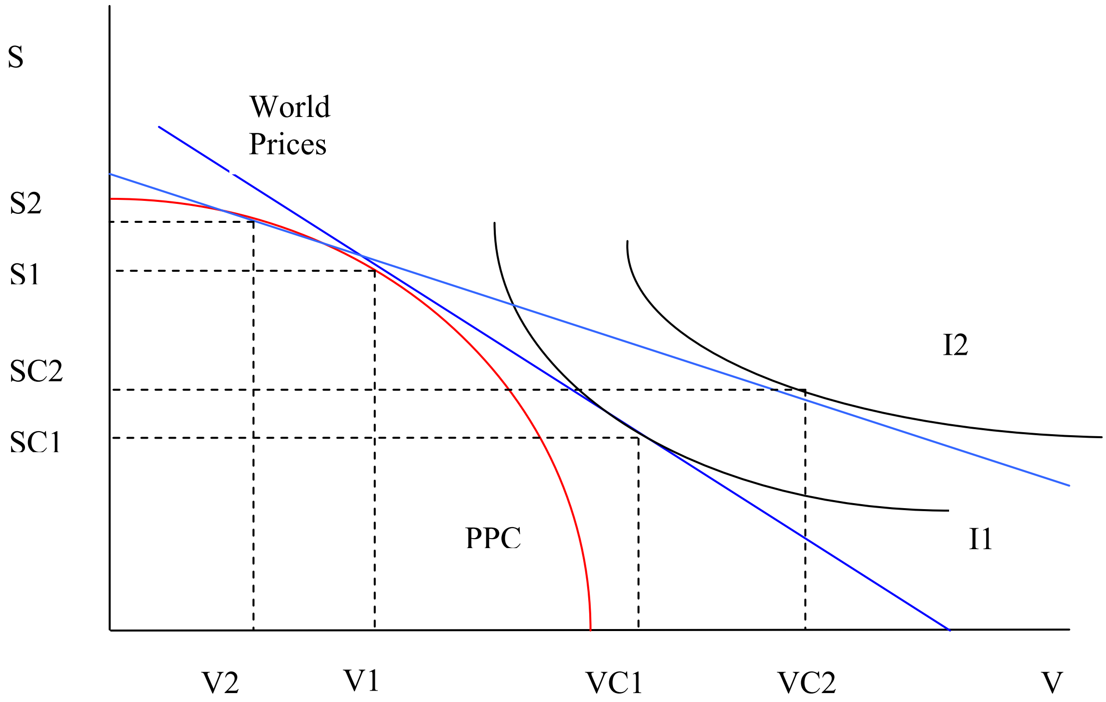
Figure 1: TFP growth and welfare using Community Indifference Curves



Primarily the growth accounting approach is concerned only with the shift in the PPC i.e. the increases in output S2 – S1 and V2 – V1. However, a welfare based approach is concerned with the change in welfare which is in fact induced by consumption changes SC2 – SC1 and VC2 – VC1. As is clear from the Figure there is no necessary correspondence between changes in output and changes in consumption. Of the increase in the output of S from S1 to S2 only a small part SC2 – SC1 contributes directly to increased welfare at home, whereas of the welfare generated by the increased consumption of V from VC2 to VC1 only V2– V1 comes directly from increased production at home.

A second scenario can also be illustrated using this framework. In Figure 2 the initial position involves a PPC curve PPC1, a given set of relative world prices and a given CIC curve I1. Assuming utility and profit maximization, output at home will then equal (S1, V1) and consumption at home will be (SC1, VC1) with exports of S being S1 – SC1 and imports of V being VC1 – V1.

Figure 2: Overseas innovation and domestic welfare



Allow that via innovation overseas the relative prices of S and V change such that V becomes relatively cheaper. This change in prices will induce changes in production at home with output of S and V changing to S2 and V2, and also changes in consumption at home to SC2 and VC2 the latter inducing increases in welfare from I1 to I2. Imports and exports will also change. The main point however is that innovation overseas increases domestic welfare.

Although conceptually informative, this approach based upon the community indifference curve can not be empirically applied for one cannot measure the CIC. Another approach is thus necessary. It does once gain however indicate that imports contribute to domestic welfare whereas exported domestic production does not.

4. The final approach discussed here is best illustrated using a macro example but can also be applied at an industry level. Logically (and in line with above arguments) welfare arises not from production per se but from expenditure upon, or consumption of, publicly and privately provided (final) goods and services. A measure of spending by domestic residents (on home produced and imported) final goods and services is given by $P_cC + P_i I + P_gG$. It would seem logical to consider such expenditure as a measure of welfare, W[6]. Thus, welfare may be defined as

(4) $W \equiv P_cC + P_iI + P_gG$

From (1) it is then clear that

(5) $W = GDP - P_xX + P_mM$

which incorporates the view that, in an open economy, GDP is not likely to be an ideal measure of welfare because GDP is a measure of output produced by domestic residents and not spending/consumption by domestic residents. The two main factors that drive a wedge between output and welfare are: output exported, which does not contribute to welfare at home (it is not part of domestic expenditure on goods and services) but rather contributes to welfare overseas[7]; and final goods imported that meet some of the domestic spending demands and thus may contribute to welfare at home.

The four approaches above all indicate that welfare generated in an economy cannot be measured solely by looking at output in that economy except when there is no international trade or when exports and imports completely cancel each other out. Output is only a reasonable measure of welfare under autarky.

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[6] Investment might be considered as investment in future consumption. Weitzman (1976) argues that (total) investment ought not to be considered as welfare generating in its year of installation. Strictly he is correct. However the required corrections to the analysis have not been undertaken in other exercises with which we wish to compare and thus they have not been carried out here.

[7] Like all good ideas, we are not the first to travel this way. Skytesvall and Hagen (2006) seem to be heading in the same direction when they say that "If a country's export is dominated by products and services that are produced by industries with high TFP growth sold on very competitive markets, it will have to sell them at decreasing prices and thus give away a large part of the rapid TFP increase to customers in other countries"

What follows is built upon the fourth, macro approach above, the message from which is that the standard production orientated approach of exploring the impact of innovation upon GDP will not provide a full insight in to the welfare impact of innovation. In addition insight in to the factors that determine the impact of innovation on GDP is thus not likely to be informative as to the appropriate indicators of investments in innovation and any index based solely upon them, will not be reliable.

Equations (4) and (5) are the foundations of what follows, the main purpose of which is to explore the extent to which taking the welfare based approach indicated by (4) and (5) leads to different estimates of the rate of innovation than those generated from an output or GTFP based approach, and as a result some new insight in to the determinants of innovation.

4. Some theoretical preliminaries.

The simplest theoretical approach to measuring the impact of innovation assumes that there exists an aggregate Cobb Douglas production function (6) in which Y(t) is GDP or value added[8] produced in time t, K(t) is capital services employed[9] in time t, L(t) is labour services employed in time t and A(t) is total factor productivity in time t. The function exhibits constant returns to scale as in (6).

(6) $$Y(t) = A(t)K(t)^{\alpha}L(t)^{1-\alpha}$$

Perfect competition is assumed and thus the price of output equals marginal cost which equals average cost both of which are invariant with respect to output. Thus (7) holds

(7) $$MC(t) = AC(t) = (\alpha A(t))^{-1}.r(t)^{\alpha}\omega(t)1^{-\alpha}\ (\alpha/1-\alpha)^{1-\alpha}$$

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[8] In the EUKLEMS work the basic model has gross output as the dependent variable with raw materials as an input. This is an alternative.

[9] This measure includes imported capital goods. Such importation is another way in which innovation overseas can stimulate welfare and productivity in the domestic economy. There is a literature attempting to measure this contribution to GTFP (see Higon, 2007). This effect is additional to any effect measured here.

Where r and ω are the price of capital and the wage rate respectively.

The impact of innovations is defined either as (i) the increase in output that can be generated between t and t +1 through technological advance without any increase in inputs or (ii) the rate at which, for given factor prices, the cost of producing a given level of value added declines as technology changes. For the first definition, from (6) it is simple to derive (8), (where t is time, but otherwise a lower case is used to represent the log of a variable)

(8) $da/dt = dy/dt - \alpha dk/dt - (1-\alpha)dl/dt$

and from (7) - dlogMC(t)/dt = da/dt. Thus by either approach, the impact of innovation is given by da/dt, the rate of growth of Total Factor Productivity. Hereinafter da/dt calculated in either way is labelled GTFP or λ_h. It can be calculated by either route but is usually measured by the difference between the rate of growth of output and the weighted sum of the growth of the two inputs (i.e. by using (8)).

In such measurement exercises value added[10] is calculated as in (3)

(3) $GDP(t) = P_q(t)Q(t) – P_z(t)Z(t)$

and as such GDP(t) may change because either prices or quantities change. In order to get a measure of changes in real value added two approaches are used. In the first, single deflated value added, changes in both $P_q(t)Q(t)$ and $P_z(t)Z(t)$ are deflated by changes[11] in $P_q(t)$. In the second, double deflated value added, changes in $P_q(t)Q(t)$ are deflated by changes in $P_q(t)$ while changes $P_z(t)Z(t)$ are deflated by changes in $P_z(t)$.

[10] Given that output is a value added concept imported raw material and intermediate inputs are included in the term $P_z(t)Z(t)$ so that the term $P_m(t)M(t)$ refers only to final goods. Intermediate goods exported are generally considered as final goods. It is however possible that imported innovation has more significance than found here because of this effect on intermediate inputs.

[11] In principle this index should be fully quality adjusted. In practice that is difficult to do and rarely happens. Also Stoneman (2008) argues that much innovation affects product aesthetics rather than functionality and, to date, no attempt has been made to reflect aesthetic changes in price indexes. Welfare gains may thus be somewhat greater than the indicators suggest once such changes are taken into account.

The results are often different (see Thomas and Feinstein, 2004 and Francis and Stoneman, 1995). The analysis here relies upon single deflation.

5. Measuring the impact of innovation on welfare

From (3) we may write that the increase in welfare between t and t+1 is given by (9)

(9) $W(t+1) - W(t) = GDP(t+1) - P_x(t+1)X(t+1) + P_m(t+1)M(t+1) - GDP(t) + P_x(t)X(t) - P_m(t)M(t)$

Employing single deflation and assuming that the prices earned on exported home production are the same as on sales of home production at home, (9) may be reduced to (10) where the price of GDP is implicit.

(10) $W(t+1) - W(t) = GDP(t+1) - X(t+1) + P_m(t+1)M(t+1) - GDP(t) + X(t) - P_m(t)M(t)$

Which encapsulates that for a given increase in output produced by domestic residents (GDP), the greater is the increase in exports the lower will be the increase in welfare at home but the greater is the increase in imports the higher will be the increase in welfare at home.

To explore the impact of innovation upon welfare, define such impact as the increase in welfare that can be generated between t and t +1 by technological advance without any increase in inputs. From (5)

(11) $Dw(t) = (GDP(t)/W(t))Dgdp(t). - (X(t)/W(t))Dx(t) + \Sigma_j((P_m^j(t)M^j(t)/W(t))(Dm^j(t) + Dp_m^j(t)))$

Where again lower case letters represents logs, D is used to represent a change between time periods, $P_m^j(t)M^j(t)$ is the value of imports from country j and the sum of this over j measures the value of total imports from all countries, $P_mM(t)$.

Assuming that goods for export are produced in the same way and sold at the same price as goods sold on the home market, the increase in GDP – X that will be generated by innovation at home in the absence of increases in factor inputs must equal the rate of growth of total factor productivity as conventionally defined ($\lambda_h(t)$).

Innovation at home is not expected to affect the production of imports. However innovation overseas will affect the efficiency with which imports to the domestic economy are produced. For any j, the amount in sterling spent upon imports in the domestic economy, $P_m^j(t).M^j(t)$, translates into a greater amount of final goods (quality adjusted) and thus welfare, if own currency import prices fall and the exchange rate stays the same.

Assuming a similar CRTS Cobb Douglas technology overseas as at home, and perfect competition in product markets, in the absence of changes in exchange rates and other changes (e.g. in factor prices) overseas, the price of imports may be expected to fall at the rate of TFP growth overseas, i.e. $P_m^j(t)$ will be expected to fall over time at the rate of TFP growth in country j (written as $\lambda_j(t)$).

Define

(12) $\alpha_h(t) = (GDP(t) - X(t)) / (GDP(t) - X(t) + P_m(t)M(t))$

i.e. as the share in total welfare of home production consumed at home[12]. Define also

(13) $\alpha_j(t) = P_m^j(t).M^j(t) / (GDP(t) - X(t) + P_m(t)M(t))$

as the share of total welfare imported from country j overseas. The welfare based innovation measure, i(t), indicating the growth in welfare that will be generated by innovation at home and overseas, in the absence of increases in factor inputs or changes in exchange rates is then given by (14).

[12] In certain cases this takes a negative value. This occurs when export revenues are greater than total value added at home. We have pondered whether this is a problem and decided that it reflects that intermediate and raw material inputs used in the domestic economy to produce exports are a charge on domestic welfare and thus it is correct. Imports come without any separate raw material and intermediate charge on the domestic economy which essentially counteract the effect.

(14) $i(t) = \lambda_h(t)\alpha_h(t) + \Sigma_j (\lambda_j(t)\alpha_j(t))$

This indicates that the growth in welfare from innovation arises from: (i) increases in the efficiency of production of domestically produced goods and services that are also consumed at home and (ii) reductions in the price or improvement in the quality of goods imported from overseas because of innovation overseas. This latter part is usually missed in the analysis of innovation. For example, advances in televisual technology (flat screens, HDTV, DVD players, etc) has considerably enhanced UK welfare arising from the audio visual consumer experience, whereas, innovation in the UK has enhanced welfare overseas[13], for example, increased UK exports of innovative financial services have benefited users of such services in many countries other than the UK[14].

6. Estimates: the UK macro economy

Equation (14) is central to the analysis. The purpose here is, using macro data, to (i) measure i(t) as a welfare based innovation indicator; (ii) see how different is that indicator to the commonly measured rate of growth of TFP and; (iii) explore the individual contributions of the non exported home production and import components of i(t). We first make the calculations for the UK which are followed by some comparisons for comparator countries.

6.1 Data Sources and Estimates

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[13] Gopinath, Kennedy and Roe (1995), similarly discuss a TFP effect and a terms of trade effect on welfare, but their terms of trade effect does not only reflect innovation and thus they do not separate out the imported innovation effect on welfare that we concentrate upon here.

[14] A common reaction to this statement has been that, surely UK exports contribute to UK welfare. The exports earn revenues which must be good. This fails to take into account that the welfare arises from expenditure of these revenues. If the revenues are spent on extra home produced goods or imports then welfare is increased. But only then is welfare increased. The stance adopted here has in prior discussions seemed an odd one to policy makers who continue to take a production based view. The welfare based approach says that the domestic economy benefits from innovation overseas. The production based approach often views innovation overseas as a threat to prosperity at home via any impacts upon export and import demands.

The main data sources are the EUKLEMS, the OECD Annual Accounts (Volume 1, Main Aggregates) the OECD Bilateral Trade dataset and the National Accounts report data on GDP, Exports and Total Imports. To obtain an estimate of the imports of final goods, we use the analytical Input-Output tables, which include the Import use table at basic prices. The latest analytical I_O tables published for the UK refer to 1995. We will assume that the share of final to total imported goods has remained constant for the period of analysis. For the year 1995 this share was equal to 43% according to the import use table.

The EUKLEMS database provides estimates of GTFP (value added based) obtained using Growth Accounting for the following countries: Australia, Austria, Belgium, Czech Republic, Denmark, Spain, France, Germany, Hungary, Ireland, Italy, Japan, Netherlands, Portugal, Slovenia, Sweden and the US. We also include estimates of GTFP for Canada from the OECD Productivity database. The value of imports from these countries represents around 70% of the total UK imports. The data on imports by country is drawn from the OECD Bilateral Trade dataset (2006) and spans the years 1988 to 2004. We assume that the proportion of imported final goods in total goods imported in to the UK although differing across source countries stays constant over time.

In Table 1 the results of the UK calculations are presented.

Table 1: I(t), GTFP, and the contribution of innovation to welfare: UK 1988 – 2004 (% p.a.)

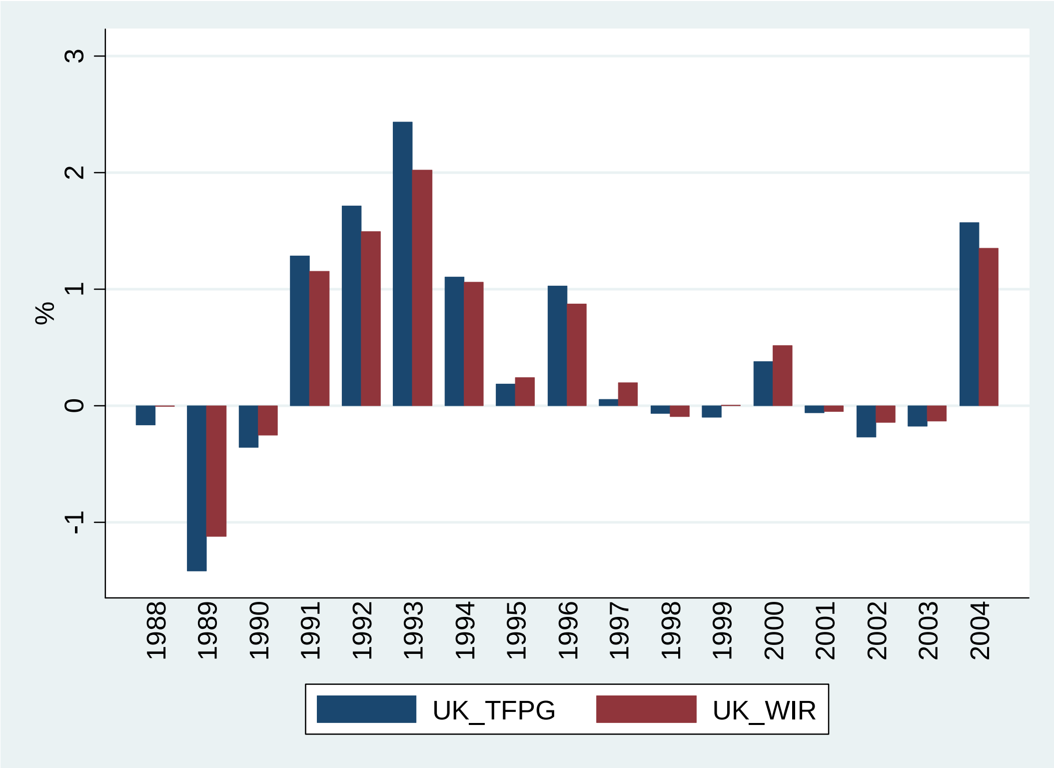
Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1988	-0.001	-0.161	-0.140	0.139
1989	-1.118	-1.413	-1.232	0.114
1990	-0.252	-0.354	-0.308	0.056
1991	1.157	1.286	1.121	0.035
1992	1.496	1.716	1.478	0.018
1993	2.020	2.434	2.053	-0.033
1994	1.061	1.106	0.912	0.149
1995	0.243	0.187	0.152	0.092
1996	0.872	1.026	0.828	0.044
1997	0.199	0.058	0.046	0.153
1998	-0.094	-0.063	-0.049	-0.045
1999	0.003	-0.097	-0.074	0.077
2000	0.517	0.383	0.291	0.225
2001	-0.049	-0.056	-0.044	-0.006
2002	-0.142	-0.265	-0.208	0.067
2003	-0.128	-0.173	-0.140	0.011
2004	1.352	1.570	1.269	0.083
Mean	0.420	0.423	0.350	0.069

Source: Authors' calculations using EUKLEMS and STAN.

6.2 UK Welfare Innovation Rate (1988-2004)

Figure 1 presents the estimated UK welfare innovation rate for the period 1988 to 2004, obtained from equation (14) and based on the data in Table 1. The series is contrasted with the growth accounting estimate of TFP growth (EUKLEMS). The welfare innovation rate is less volatile than the GTFP estimate. Both series show greater disparities during the 1990s but behave very similarly during late 1990s and beginning of 2000s.

Figure 1: Growth Rates of the Welfare Innovation rate and TFP.



Source: Authors' calculations and EUKLEMS dataset. UK_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. UK_WIR is the Welfare innovation rate obtained from equation 14.

The estimates of the mean of the of the welfare indicator i(t) and the rate of growth of TFP, $\lambda_h(t)$ over the period 1988 to 2004 are very similar at 0.420 and 0.423 respectively. This suggests that in the long run the GTFP in imported goods is not that different to that of exported goods. There are however three distinct periods in the data. Table 2 presents the annual average of the welfare indicator i(t) and the rate of GTFP, $\lambda_h(t)$ for these three different periods. For the period 1991-1995, GTFP is greater than the welfare measure while it is lower for the period 1996-2000, and in the period 2001-2004, there is no apparent difference between the two.

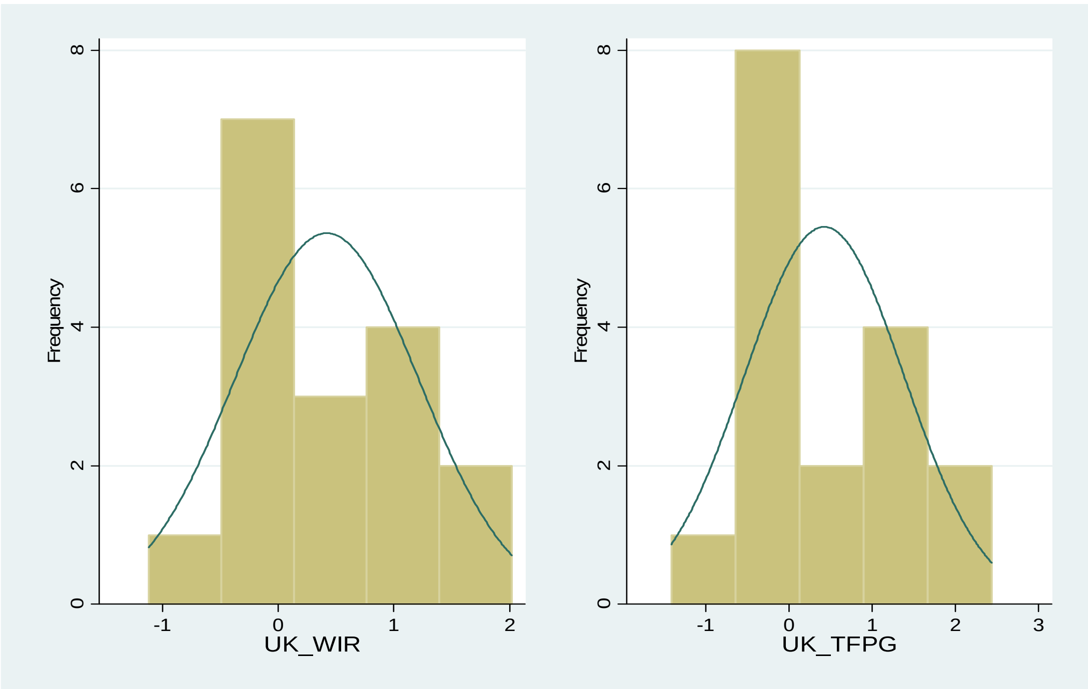
Table 2: Average Annual Growth Rates (UK)

	1991-1995	1996-2000	2001-2004
UK WIR	1.195	0.299	0.258
UK GTFP	1.346	0.262	0.269

Notes: UK_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. UK_WIR is the Welfare innovation rate obtained from equation 14.

Figure 2 presents the data in a slightly different way by plotting the frequency distribution of different values for i(t) and GTFP within five quintiles. As can be seen the differences are not substantial.

Figure 2: Histograms of UK GTFP vs. UK WIR



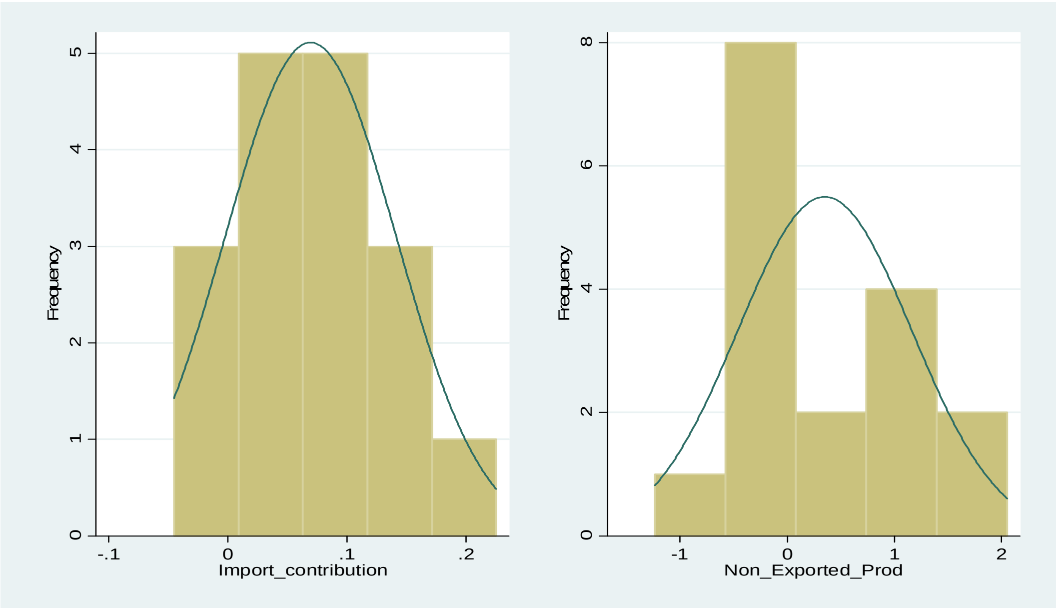
Source: Authors' calculations and EUKLEMS dataset.

Thus the welfare based indicator, although revealing some differences to the GTFP indicator does not suggest that use of a welfare based indicator will mean large revisions to the estimated impact of innovation.

There is however another issue to address. In the determination of i(t) what contribution is made by non exported production ($\lambda_h(t)\ \alpha_h(t)$) and what by imports ($\Sigma_j$ ($\lambda_j(t)\alpha_j(t)$))?. From Table 1, the mean estimate of i(t) is 0.420, the mean of ($\lambda_h(t)\ \alpha_h(t)$) is 0.350 and the mean of (Σ_j ($\lambda_j(t)\alpha_j(t)$) is 0.069. Thus the percentage of the total contribution of innovation to welfare arising from innovation in non exported home production is 83.5 % and the percentage contribution from imports is 16.5%.

Although the contribution of imports is the smaller of the two, that contribution is less volatile than the contribution from innovation in non exported production. This is illustrated in the following histograms which show the frequency within which annual estimates fall within five quintiles.

Figure 3: Histograms of Import and non-exported production contribution to the WIR



Source: Authors' calculations and EUKLEMS dataset.

These results indicate that via growth accounting, a concentration upon domestic production and GTFP ignores that in the UK some 16.5% of the increase in welfare generated by innovation is the results of innovation overseas rather than at home. This ought to be taken into account in the calculation of an index.

7. Estimates of WIR for a sample of OECD Counties

7.1 Data Sources and Estimates

The OECD countries for which we replicate the analysis conducted in the previous section are the following: Canada, France, Germany, Italy, Japan, Spain and the US. The data on GTFP estimates is drawn from the EUKLEMS dataset while data on GDP, exports and total imports comes from the OECD Nationals Accounts (2008). GTFP estimates from Canada are provided by the OECD Productivity dataset. Bilateral data on imports is collected from the OECD Bilateral Trade dataset (2005). To obtain an estimate of the imports of final goods, we use the 1995 OECD Input-Output tables, which include the import use table at basic prices. We assume that the share of final to total imported goods has remained constant for the period of analysis.

Table 3 presents the shares of final demand in total imported goods for the sample of countries according to the 1995 input-output tables (OECD). The lowest share belongs to Italy, with 26.5%; while for Canada nearly 50% of the imported goods go to final demand (the other half are intermediate inputs of production). Germany, with 42.3%, and the UK (43%) have very similar percentages.

Table 3: Share of final demand to total imported goods by country (%, 1995)

	Canada	France	Germany	Italy	Japan	Spain	US
m_j	47.3	38.4	42.3	26.5	37.9	32.4	46.7

Source: Data from the OECD Input –Output database.

7.2 Estimates of the Welfare Innovation Rate (WIR)

In this section we provide, for comparative purposes, similar estimates as those provided for the UK above, for the seven OECD countries over the 1988 – 2004 period. These are summarised here with detail provided for each country in Appendix 2. In Table 4 we list the mean (over the period 1988 – 2004) per annum estimates for the seven countries of GTFP ($\lambda_h(t)$), i(t) and the contribution made by imports (Σ_j ($\lambda_j(t)\alpha_j(t)$) to i(t) in levels and as a percentage.

Table 4: GTFP, WIR and the contribution of imports, international comparisons, means p.a. 1988 – 2004

Country	i(t)	GTFP	Σ_j ($\lambda_j(t)\alpha_j(t)$ (%)
UK	0.420	0.423	0.069 (16.43)
Canada	0.580	0.600	0.125 (21.55)
France	0.620	0.656	0.034 (5.43)
Germany	0.756	0.814	0.046 (6.08)
Italy	0.376	0.371	0.026 (6.91)
Japan	0.484	0.496	0.010 (2.02)
Spain	-0.367	-0.292	0.035 (*)
USA	0.783	0.824	0.015 (1.92)

The interesting point is that the contribution of imported innovation to domestic welfare growth differs considerably across countries. For Japan and the USA imported innovation matters little. For France, Germany and Italy it matters but not to a large degree. To the UK and Canada it matters a lot. For Spain it is the only bright spot in a sad overall picture.

9. Estimates: UK Industry level

The estimates above are at the macro level for different countries. Within the macro economy individual industries will have very different pattern of imports and exports and as such, across industries, there may be larger and smaller differences between GTFP and i(t) and also different contributions of imports and non exported home production to i(t). In order to obtain some idea of differences across industries the first step is to equate, perhaps rather crudely, industries and markets. One may then again use EUKLEMS estimates of GTFP for different countries, but now at the industry level.

Data sources

The EUKLEMS data enables a disaggregation in to 10 manufacturing industries (as listed in Table 5). However there are problems with getting a sufficiently fine breakdown of final good imports by industry by source. The bilateral data on exports and total imports at the 2 digit industry level comes from the OECD National Accounts (2008), while the data on total exports and imports is drawn from the ONS UK Trade in goods analyzed in terms of industry (MQ10). To obtain an estimate of the imports of final goods by industry, we use the 1995 OECD Input-Output tables, which include the import use table at basic prices. We assume that the share of final to total imported goods has remained constant for the period of analysis.

Table 5 presents the share of final demand in total imported goods for the sample of UK manufacturing industries according to the 1995 input-output tables (OECD). The lowest share belongs to the Paper industry with just 8%; while for the Food and Manufacturing not elsewhere classified 68% and 86% respectively of the imported goods go to final demand. In general we observe a high degree of heterogeneity across industries with respect to the percentage of imported imports destined for final demand (as opposed to intermediate production).

Table 5: Share of final demand in total imported goods by industry in the UK (%, 1995)

Industry	**m_j**
Total Manufacturing	45
Food, Tobacco, Beverages	68
Textiles, textile products, leather and footwear	59
Wood and products of wood and cork	13
Pulp, paper, paper products, printing and publishing	8
Chemical, rubber, plastics and fuel products	15
Other non-metallic mineral products	21
Basic metals and fabricated metal products	18
Machinery and equipment n.e.c.	59
Electrical and optical equipment	50
Manufacturing n.e.c.	86

Source: Data from the OECD Input-Output database (1995).

Estimates of the Welfare Innovation Rate

In this section, we provide estimates of the welfare innovation rate alongside the growth of TFP for the listed UK Manufacturing industries over the period 1990-2004. These are summarized in Table 6 with detail provided for each industry in Appendix 3. We report the annual average (over the period 1990-2004) estimates of GTFP and the welfare innovation rate (i(t)) for manufacturing industry as a whole and for ten manufacturing sectors. In addition we also report the contribution made by imports ($\Sigma_j \lambda_j(t)\alpha_j(t)$).

Table 6: GTFP, WIR and the contribution of imports, industry comparisons, means p.a. 1990 – 2004

Industry	i(t)	GTFP	$\Sigma_j \lambda_j(t)\alpha_j(t)$ (%)
Total Manufacturing	**1.463**	**1.539**	**1.303 (89.1)**
Food, Beverages and Tobacco	0.046	-0.197	0.111 (241.3)
Textiles, textile products, leather and footwear	0.565	1.428	0.454(80.3)
Wood and products of wood and cork	-0.738	-1.011	0.148
Pulp, paper, paper products, printing and publishing	-0.212	-0.243	0.022
Chemical, rubber, plastics and fuel products	-0.709	2.006	-2.265
Other non-metallic mineral products	1.714	1.872	0.097 (5.6)
Basic metals and fabricated metal products	1.049	1.271	0.311(29.6)
Machinery and equipment n.e.c	1.045	1.105	1.876(179.5)
Electrical and optical equipment	3.931	3.815	0.963(25.4)
Manufacturing n.e.c.	-0.263	-1.678	0.169

Source: Authors' calculations and EUKLEMS dataset.

From Table 6 we observe that the differences between the welfare innovation rate and GTFP are much more pronounced across industries than found at the aggregate level. Large disparities between the two indices are found for the Chemical and the Manufacturing n.e.c. sectors; while small differences are found for the Paper and the Machinery industries respectively. The contribution of imports to the welfare innovation rates varies significantly across industries, but is positive in all except Chemicals.

The results also indicate that the contribution of imports to welfare growth differs considerably across industries. In all but Chemicals the contribution is positive, in some cases offsetting a negative contribution from GTFP. That contribution is also in most of these industries considerably greater than when the whole economy was being studied. The estimate for manufacturing of 89.1% compares with our industry wide estimate of 16.5%.

10 Accounting vs. causality

The results that have been presented above use the techniques of growth accounting and show that, in some countries and industries, the impact of innovation on GTFP and on welfare may be different, and that in some countries/industries much of the impact of innovation upon welfare comes via imports of improved (or cheaper) final goods. This is an important new observation.

It is however necessary to point out that the techniques employed here are accounting techniques and as such indicate the outcomes and not the causes of those outcomes. So although in the UK in aggregate some 17.5% of the increase in welfare is due to imports, no explanation is offered as to why the import share is what it is or why GTFP in different countries and industries take the values that they do. That is another step.

11. Conclusion

The driving force behind this paper is to contribute to the development of an innovation index. The main line of argument is that the index is to reflect inputs to innovation and as such it is necessary to indicate what are the outputs of innovation so that drivers may be identified. It was emphasized that the output of innovation could best be defined in welfare terms. The welfare approach indicated that innovation provides benefits at home and overseas and thus UK exports do not (directly) yield benefits at home, whereas innovation brought in to the UK via imported final goods does provide welfare in the UK. This results in a direct contrast with the often stated viewpoint that the growth of total factor productivity (GTFP) is the best (and only measure) of innovation. An innovation output indicator reflecting these ideas was developed.

Estimates of the indicators for the 1988 – 2004 period showed that although at the aggregate level there is little difference between welfare based measure and GTFP, the import component[15] of welfare growth induced by innovation may be significant and thus merits attention. The relevance of imported innovation is shown to differ across countries, being particularly important in the UK and Canada but of less importance elsewhere.

Inter industry comparisons using UK data show that in some markets/industries the extent of the difference between GTFP and the welfare indicator is much greater than seen in the macro data. This highlights the importance of the choice between welfare and output based indicators. The importance of imported innovation also differs considerably across markets/industries in the UK, the contribution being positive in all industries studied except chemicals. In manufacturing as a whole it is calculated that on average 1990 – 2004, 89% of the increase in welfare per annum is due to imported innovation (although in, for example, non metallic minerals, it is only 5.7%).

Given these findings, in any exercise undertaken to index innovation in the UK, the imported element should be catered for. The ideal means of doing so is a matter for further analysis. This and other further work that would be desirable with associated timing and costings is detailed in Appendix 1.

[15] The total contribution of imports comes via intermediate inputs, capital goods and the final goods concentrated upon here. There are estimates of the contribution of the second of these in the literature (Higon, 2007) and Battisti and Stoneman (2007) look at the first. Here however the interest has been only with the third.

REFERENCES

G. Battisti and P. Stoneman (2007),“The Prices of Material and Intermediate Inputs in UK Manufacturing: an ECM approach to identifying the contributions of world prices and domestic factor costs”, *Applied Economics*, 2007 (April), 39, 7, 859 – 882.

G Battisti, A Mourani, and P. Stoneman (2008), “Devising a Methodology for an Innovation Scoreboard”, presented at the Royal Economic Society Conference, Warwick University, March, 2008.

N. Francis and P. Stoneman (1995), "Double Deflation and The Measurement of Output and Productivity in UK Manufacturing 1979-1989", *Journal of the Economics of Business*, 1,3, 423-437.

M. Gopinath, P. L Kennedy and T L. Roe (1995), “Trade, growth, and welfare linkages in North America: An empirical analysis” *The North American Journal of Economics and Finance*. Volume 6, Issue 2, 189-201

D A Higon (2007), The impact of R&D spillovers on UK manufacturing TFP: A dynamic panel approach, *Research Policy*, 2007, vol. 36, issue 7, pages 964-979

N. Oulton (2004), "Productivity Versus Welfare: Or GDP Versus Weitzman's NDP" . *Review of Income and Wealth*, Vol. 50, No. 3, pp. 329-355, September 2004

R D Pindyck and D L Rubinfioeld (1998), *Microeconomics*, Fourth Edition, Prentice Hall, New Jersey.

T Skytesvall and H-O Hagen (2006) “Does Sweden give away its TFP for free?” *OECD Workshop on Productivity Analysis and Measurement*, Bern 16-18 October .

P. Stoneman (2008), “The Economics of Soft Innovation: a study of changes in product aesthetics and aesthetic products”, presented at the Royal Economic Society Conference, Warwick University, March, 2008.

M. Thomas and C Feinstein (2004), “The value added approach to the measurement of economic growth” in, T. Guinnane, W. Sundstrom and W. Whatley (eds.), *History Matters: Essays on Economic Growth, Technology and Demographic Change*, Stanford University Press, 425 - 458

M. Weitzman, (1976). On the welfare significance of national product in a dynamic economy. *Quarterly Journal of Economics*. 90, 156–162.

APPENDIX 1 FURTHER WORK

1. The most obvious extra work to be completed is the extension of the market/industry level analysis to countries other than the UK. This is both data and time intensive and thus costly.
2. Given that the work undertaken here has been done quickly there is a need to spend some time further checking the results.
3. The translation of the results in to implications for an index depends to large extent upon decisions yet to be made as to the nature of the index. Once these have been made the issue of incorporation needs consideration.
4. The exercise performed here is an exercise in accounting. There is a need to more fully consider determinations of outcomes rather than outcomes per se..
5. The findings that innovations imported in final goods are important calls for some analysis of policy implications.

Such work can be undertaken by the same researchers, with a time estimate of 24 days at a cost (including expenses) of £525 per day and a total cost of at a cost of £12,600, and a completion date of January 2009.

APPENDIX 2: NON UK ESTIMATES, THE DETAIL

Canada

Table A2.1 lays out the basic data for Canada. Although the i(t) and $\lambda_h(t)$ measures yield similar mean estimates over the period 1988 to 2004, the percentage of the total contribution of innovation to welfare in Canada arising from innovation in non exported home production is 78.5% whereas the percentage contribution from

Table A2.1: i(t), its component parts, and GTFP: Canada, 1988 – 2004 (% p.a.)

year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1988	0.463	0.300	0.257	0.206
1989	-0.336	-0.400	-0.344	0.008
1990	-0.877	-1.000	-0.859	-0.018
1991	-0.860	-1.000	-0.860	0.001
1992	0.849	0.800	0.679	0.170
1993	0.351	0.500	0.415	-0.064
1994	1.576	1.700	1.376	0.200
1995	0.664	0.900	0.716	-0.051
1996	-0.158	-0.300	-0.237	0.080
1997	2.418	3.000	2.320	0.098
1998	0.779	1.100	0.834	-0.055
1999	1.651	1.800	1.355	0.297
2000	1.893	2.100	1.560	0.333
2001	0.037	0.000	0.000	0.037
2002	1.055	0.900	0.692	0.363
2003	0.027	-0.300	-0.238	0.264
2004	0.335	0.100	0.079	0.255
Mean	0.580	0.600	0.456	0.125

Source: Authors' calculations and OECD Productivity dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the OECD Productivity dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

imported innovation is 21.5%. This contribution is significantly larger than for the UK and, as will be seen below, the largest in any of the sample of OECD countries reviewed in this report. These results indicate concentration upon domestic production and GTFP would ignore that in Canada some 21.5% of the increase in welfare generated by innovation is the result of innovation overseas rather than at home.

Figure A2.1 presents graphically the estimates of i(t) for Canada, obtained from equation (14), and the TFP growth rate for the period 1988 to 2004. As in the UK case, the difference between the two series is not very pronounced although i(t) is slightly less volatile than the GTFP estimate. The differences between the two series are most noticeable during the second half of the 1990s and the beginning of the 2000s (see Table A2.2).

Figure A2. 1: Growth Rates; i(t) and GTFP, Canada

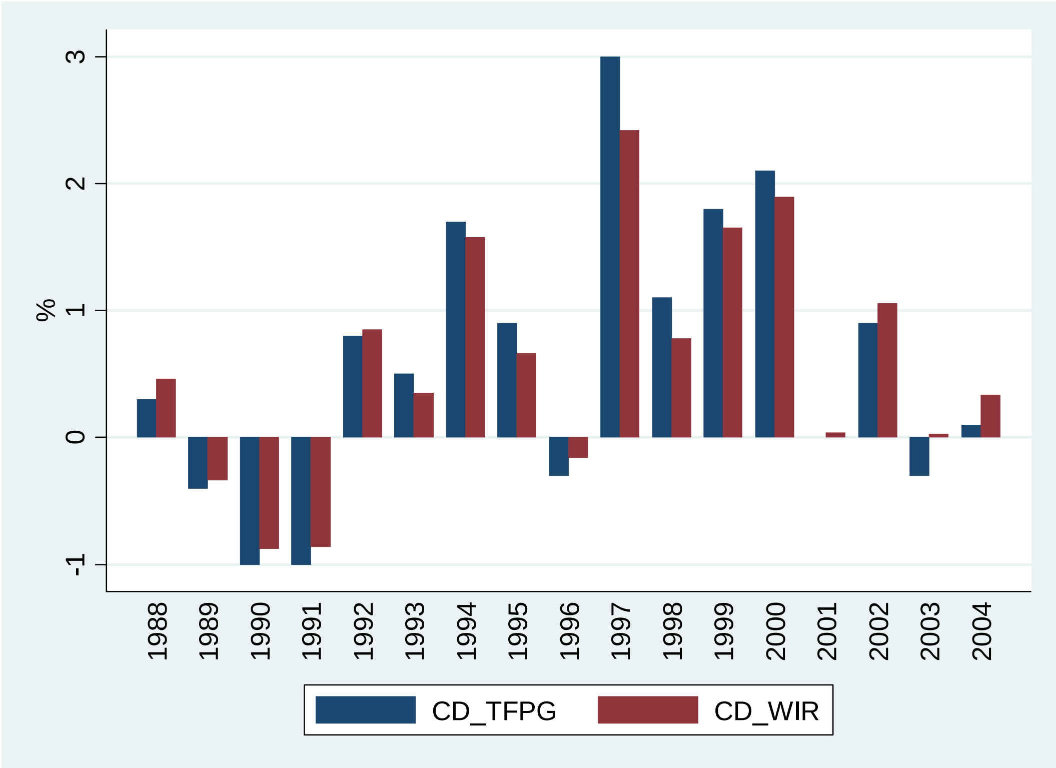


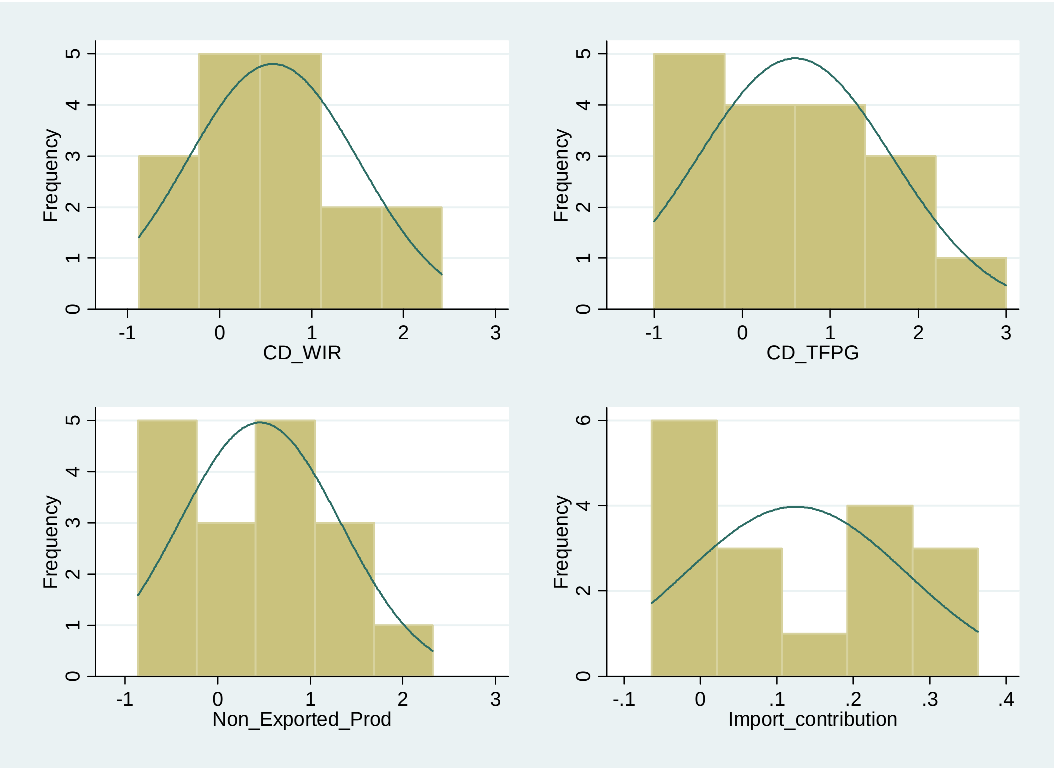
Table A2. 2: Average Annual Growth Rates (Canada)

	1991-1995	1996-2000	2001-2004
i(t)	0.516	1.317	0.363
GTFP	0.580	1.540	0.175

Notes: GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. I(t) is the Welfare innovation rate obtained from equation 14.

Figure A2.2 presents the data in a slightly different way by plotting the frequency histogram of different values for i(t), TFP growth rate, the contribution to i(t) from the non-exported production and the contribution from imports within five quintiles. As can be seen the differences between i(t) and GTF for Canada are more pronounced than in the UK case.

Figure A2. 2: Histograms, Canada



Source: Authors' calculations and OECD Productivity dataset.

France

Table A2.3 lays out the basic data for France. Once more the i(t) and $\lambda_h(t)$ mean measures yield similar estimates. The percentage of the total contribution of innovation to welfare in France arising from innovation in non exported home production is 94.5% and the percentage contribution from imports is 5.5%. The contribution from imports to innovation welfare in France is significantly smaller than in the UK and Canada.

Table A2.3: I(t) , its component parts, and GTFP: France, 1988 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1988	1.615	1.674	1.516	0.098
1989	2.149	2.310	2.076	0.073
1990	-0.167	-0.239	-0.215	0.048
1991	-0.032	-0.087	-0.078	0.047
1992	0.461	0.486	0.440	0.021
1993	-0.633	-0.691	-0.629	-0.004
1994	0.939	0.927	0.841	0.099
1995	1.320	1.403	1.267	0.053
1996	-0.622	-0.705	-0.636	0.013
1997	0.859	0.901	0.806	0.053
1998	1.363	1.594	1.419	-0.056
1999	0.311	0.331	0.294	0.017
2000	1.860	2.023	1.761	0.098
2001	-0.445	-0.500	-0.437	-0.008
2002	1.033	1.171	1.033	0.001
2003	0.521	0.606	0.538	-0.017
2004	0.001	-0.048	-0.043	0.043
Mean	0.620	0.656	0.585	0.034

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

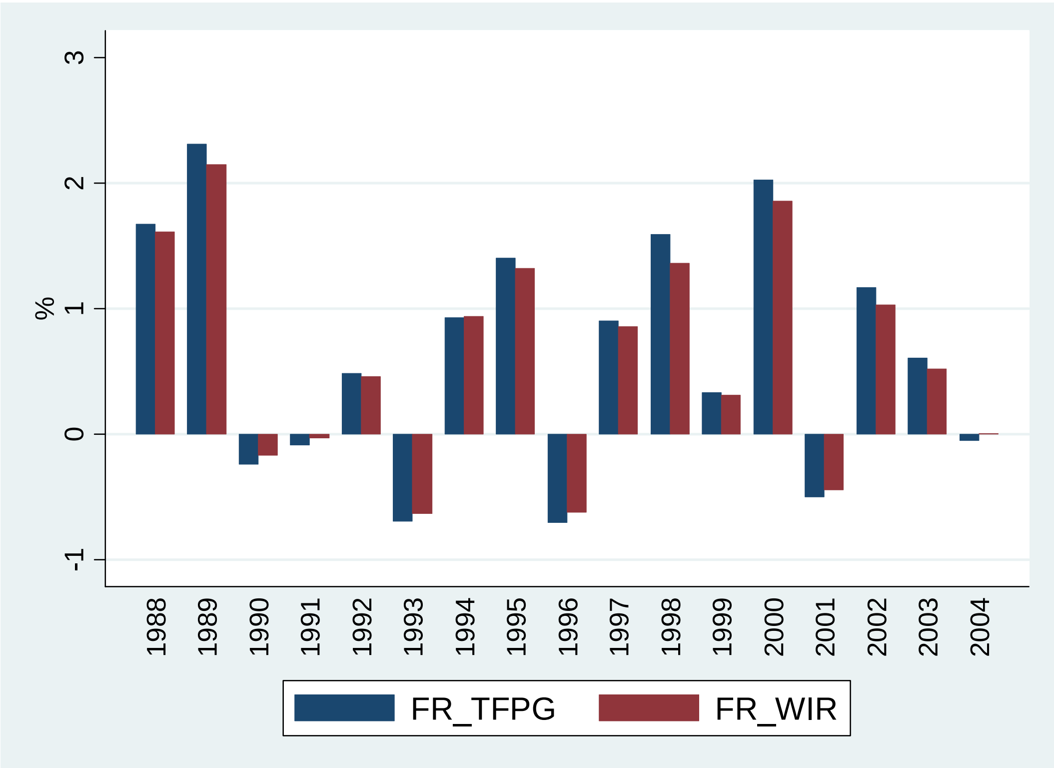
In Table A2.4, we distinguish three periods. The estimates of the average of GTFP TFP growth and i(t) are almost identical for the first half of the 1990s. The difference between the two series, although relatively small, is largest during the second half of the 1990s. Figure A2.3 presents graphically i(t) obtained from equation (14), together with the TFP growth rate (from EUKLEMS) over the period 1988 to 2004. As in the UK case, there is little difference between the two series, and i(t) is slightly less volatile than the GTFP estimate.

Table A2.4: Average Annual Growth Rates (France)

	1991-1995	1996-2000	2001-2004
i(t)	0.411	0.754	0.277
GTFP	0.408	0.829	0.307

Notes: FR_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. i(t) is the Welfare innovation rate obtained from equation 14.

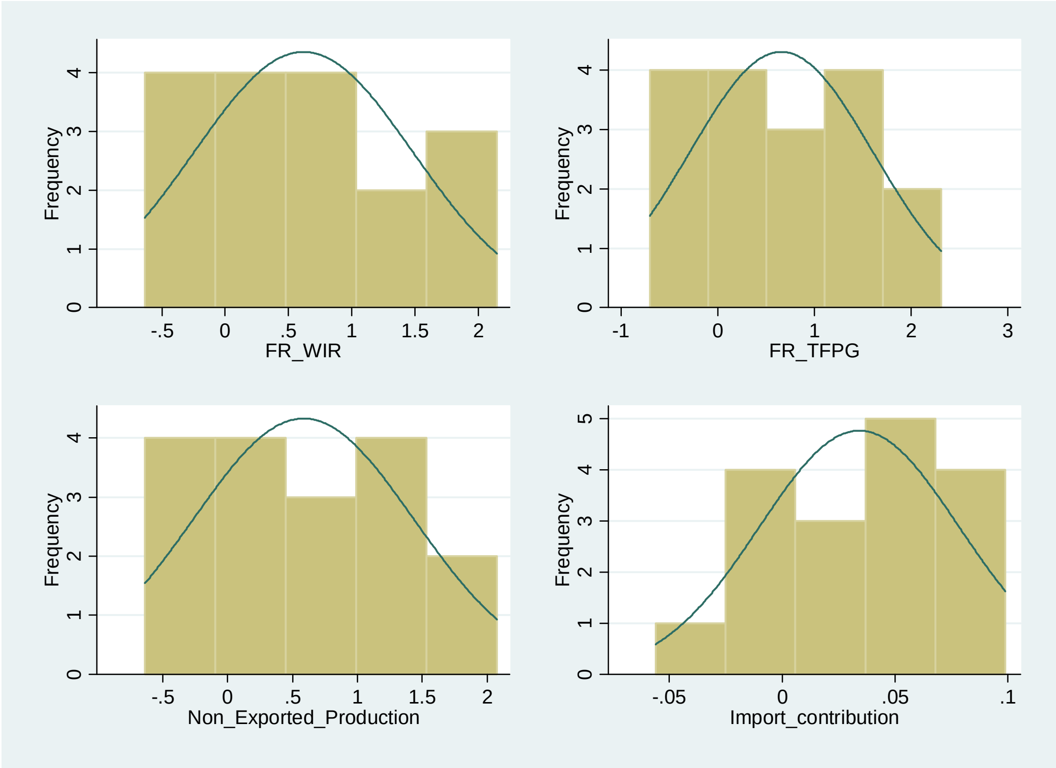
Figure A2.3: Growth Rates; i(t) and GTFP, France



Source: Authors' calculations and EUKLEMS dataset. FR_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. FR_WIR is i(t) obtained from equation 14.

Figure A2.4 presents the data in a slightly different way by plotting the frequency histograms of different values for i(t), the contribution to i(t) from the non-exported production and the contribution from imports within five quintiles. As can be seen the differences between i(t) and GTFP for France are not substantial (and the contribution of the non-exported domestic production follows a very similar distribution to the GTFP).

Figure A2.4: Histograms, France



Germany

Data for Germany is presented in Table A2.5. The i(t) and $\lambda_h(t)$ mean measures yield similar estimates, with average TFP growth estimate slightly greater than the welfare innovation rate (0.76%) for the period 1988 to 2004. The percentage of the total contribution of innovation to welfare in Germany arising from innovation in non exported home production is 93.9% and the percentage contribution from imports is 6.1%. The contribution from imports is very similar to that for France but significantly less than that in the UK and Canada.

Table A2.5: i(t), its component parts, and GTFP: Germany, 1988 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1988	1.508	1.578	1.400	0.107
1989	1.995	2.172	1.909	0.086
1990	1.859	2.087	1.831	0.028
1991	1.741	1.982	1.725	0.017
1992	0.526	0.582	0.512	0.014
1993	-0.456	-0.507	-0.452	-0.003
1994	1.311	1.367	1.214	0.097
1995	1.311	1.420	1.256	0.056
1996	1.047	1.186	1.045	0.002
1997	0.931	1.011	0.877	0.054
1998	-1.108	-1.285	-1.106	-0.002
1999	0.240	0.245	0.209	0.030
2000	1.749	1.943	1.606	0.143
2001	0.251	0.315	0.260	-0.009
2002	0.059	0.034	0.028	0.031
2003	-0.321	-0.411	-0.340	0.020
2004	0.206	0.115	0.094	0.112
Average	0.756	0.814	0.710	0.046

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

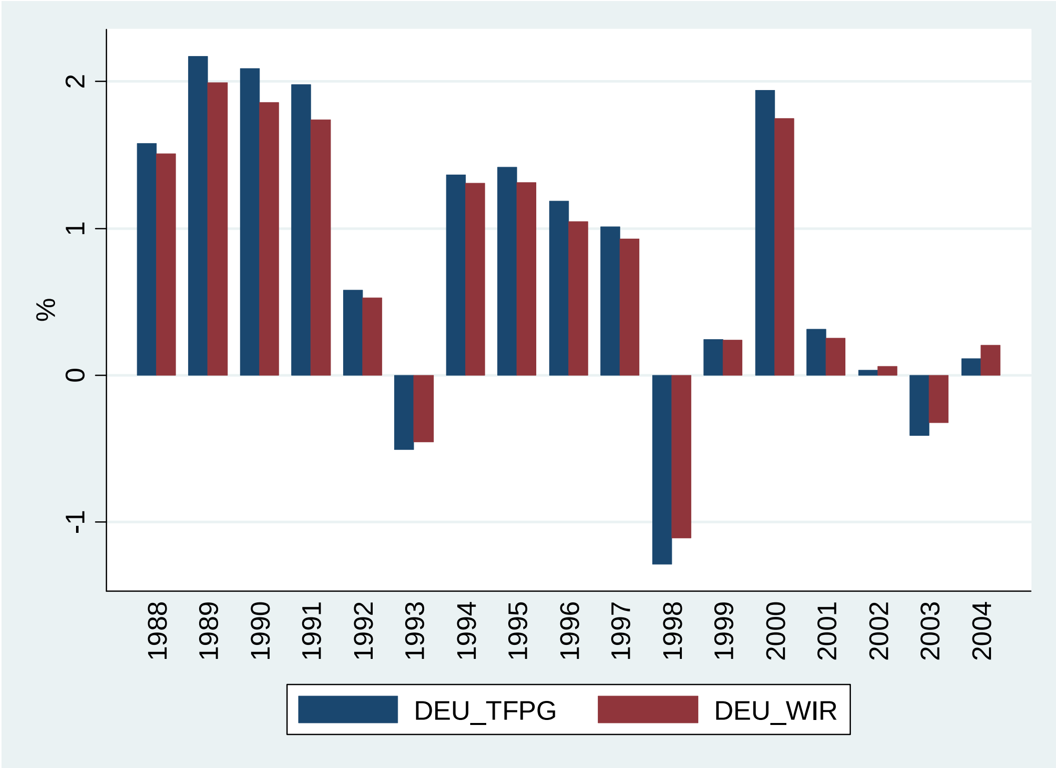
Across time periods we observe almost no difference between the two series in the case of Germany; the largest gap between the two being for the first half of the 1990s (see Table A2.6). Figure A2.5 presents graphically the estimated German welfare innovation rate, obtained from equation (14), together with the TFP growth rate over the period 1988 to 2004. There is little difference between the two series, though once more, i(t) is slightly less volatile than the GTFP estimate.

Table A2.6: Average Annual Growth Rates (Germany)

	1991-1995	1996-2000	2001-2004
i(t)	0.887	0.572	0.049
GTFP	0.969	0.620	0.013

Notes: DEU_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. i(t) is the Welfare innovation rate obtained from equation 14.

Figure A2.5: Growth Rates; i(t) and GTFP , Germany



Source: Authors' calculations and EUKLEMS dataset. DEU_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. DEU_WIR is the Welfare innovation rate obtained from equation 14.

Italy

Data for Italy is presented in Table A2.7. Once more the i(t) and $\lambda_h(t)$ mean measures yield similar estimates. For Italy the average TFP growth estimate (0.37%) is slightly less than the welfare innovation rate (0.38%) for the period 1988 to 2004. The percentage of the total contribution of innovation to welfare in Italy arising from innovation in non exported home production is 93.2% and the percentage contribution from imports is 6.8%. The latter is very similar to that for France and Germany and significantly inferior to that for the UK and Canada.

Table A2.7: i(t), its component parts, and GTFP: Italy, 1988 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1988	1.933	1.992	1.881	0.052
1989	2.047	2.121	1.995	0.052
1990	0.152	0.131	0.123	0.029
1991	-0.076	-0.109	-0.103	0.027
1992	0.317	0.319	0.301	0.015
1993	0.686	0.739	0.696	-0.010
1994	2.747	2.878	2.699	0.049
1995	1.832	1.930	1.790	0.042
1996	-0.919	-0.997	-0.932	0.013
1997	0.765	0.783	0.728	0.036
1998	-1.111	-1.191	-1.105	-0.006
1999	-0.282	-0.322	-0.298	0.016
2000	1.382	1.429	1.306	0.077
2001	-0.036	-0.033	-0.030	-0.006
2002	-1.206	-1.331	-1.223	0.017
2003	-1.424	-1.546	-1.426	0.003
2004	-0.417	-0.487	-0.448	0.031
Average	0.376	0.371	0.350	0.026

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

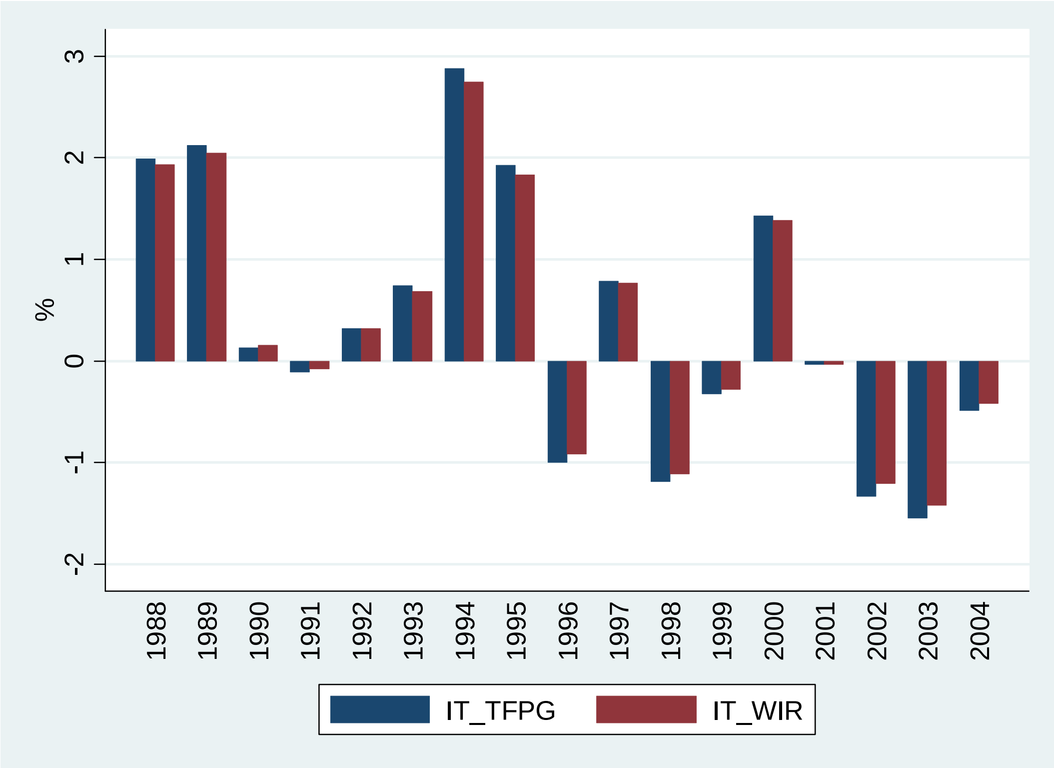
Table A2.8 presents the annual average estimates across different periods. For both i(t) and GTFP there is a positive rate for the first half of the 1990s and a negative rate for the later periods. As can be seen, i(t) is also less volatile. Post 1996 although imported innovation makes a negative contribution to welfare growth, it is a smaller negative than the negative rate of GTFP growth. Figure A2.6, graphically presents i(t) and GTFP over the period 1988 to 2004.

Table A2.8: Average Annual Growth Rates (Italy)

	1991-1995	1996-2000	2001-2004
i(t)	1.101	-0.033	-0.771
GTFP	1.151	-0.060	-0.849

Notes: IT_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. i(t) is the Welfare innovation rate obtained from equation 14.

Figure A2.6: Growth Rates, i(t) and GTFP Italy



Source: Authors' calculations and EUKLEMS dataset. IT_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. IT_WIR is the Welfare innovation rate obtained from equation 14.

Japan

Data for Japan is displayed in Table A2.9. For the period 1988 to 2004, the average TFP growth estimate (0.50%) is slightly higher than the estimate of i(t) (0.48%), although the difference is small. Using this data, the percentage of the total contribution of innovation to welfare in Japan arising from innovation in non exported home production is 97.9% and the percentage contribution from imports is just 2.1%. The contribution from imports to the innovation welfare in Japan is one of the lowest of the selected sample of OECD countries considered in this report.

Table A2.9: i(t), its component parts, and GTFP: Japan, 1988 – 2004 (% p.a.)

Year	$i(t)$	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1988	4.257	4.407	4.236	0.021
1989	1.974	2.059	1.973	0.001
1990	2.100	2.183	2.103	-0.004
1991	0.807	0.832	0.805	0.002
1992	-1.273	-1.328	-1.290	0.018
1993	-0.366	-0.375	-0.364	-0.002
1994	-0.430	-0.464	-0.449	0.019
1995	0.145	0.147	0.142	0.003
1996	1.626	1.685	1.618	0.008
1997	-0.138	-0.158	-0.152	0.014
1998	-1.551	-1.608	-1.552	0.001
1999	0.162	0.150	0.144	0.018
2000	0.775	0.786	0.754	0.021
2001	-0.896	-0.940	-0.902	0.006
2002	-0.567	-0.611	-0.585	0.018
2003	0.977	1.011	0.963	0.013
2004	0.630	0.650	0.615	0.015
Average	0.484	0.496	0.474	0.010

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. $i(t)$ is the Welfare innovation rate obtained from equation 14.

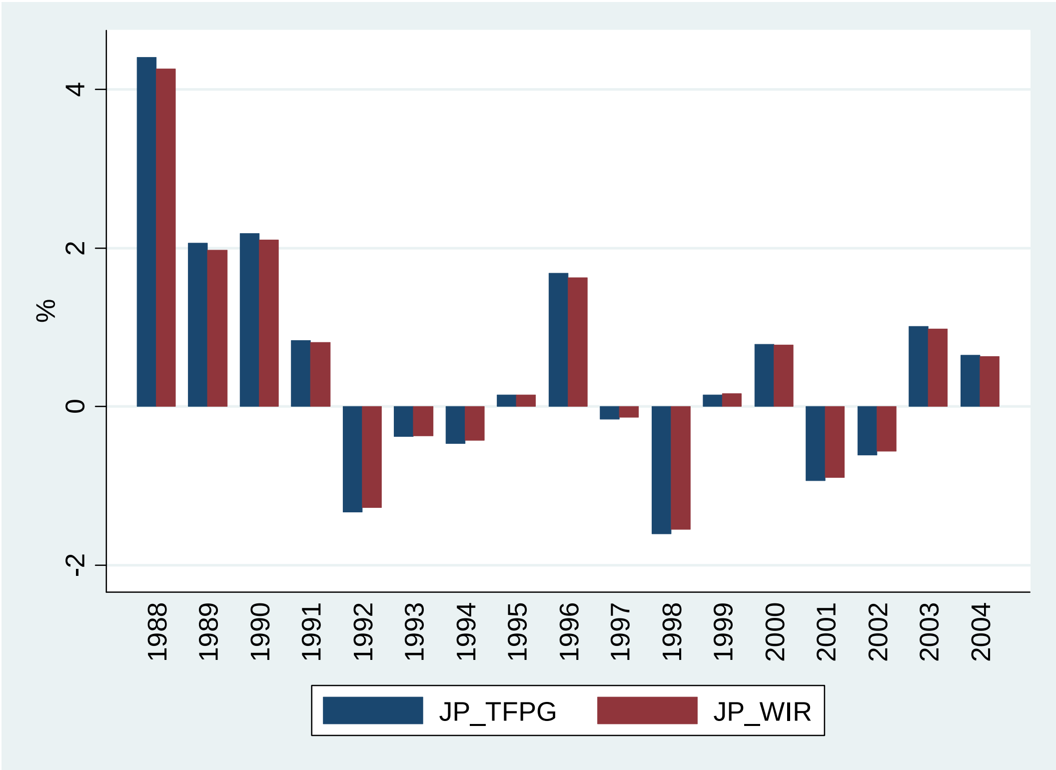
Table A2.10 presents the annual average estimates across different periods. Both sets of estimates report a negative rate for the first half of the 1990s and a positive rate for the later periods. As we can observe, the differences between the two series are minimal. Figure A2.7 presents graphically the estimated Japanese welfare innovation rate together with the TFP growth rate over the period 1988 to 2004.

Table A2.10: Average Annual Growth Rates (Japan)

	1991-1995	1996-2000	2001-2004
i(t)	-0.224	0.175	0.036
GTFP	-0.238	0.171	0.028

Notes: JP_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. WIR is the Welfare innovation rate obtained from equation 14.

Figure A2.7: Growth Rates, i(t) and TFP, Japan



Source: Authors' calculations and EUKLEMS dataset. JP_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. JP_WIR is the Welfare innovation rate obtained from equation 14.

Spain

Data for Spain is presented in Table A2.11. For the period 1988 to 2004, in contrast to the rest of the OECD countries reported, both the average annual TFP growth estimate (-0.367%) and i(t), the welfare innovation rate, (-0.292%) are negative. Using the data reported in Table A2.11, the percentage of the total contribution of innovation to welfare loss in Spain arising from innovation in non exported home production is 112.1% and the percentage contribution from imports is negative, therefore welfare enhancing, and equal to -12.1%. These results indicate that via growth accounting, a concentration upon domestic production and GTFP would underestimate the increase in welfare generated by innovation by 12 %.

Table A2.11: i(t), its component parts, and GTFP: Spain, 1988 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1988	1.902	1.962	1.826	0.076
1989	-1.261	-1.436	-1.331	0.070
1990	-0.532	-0.602	-0.560	0.028
1991	0.395	0.394	0.367	0.028
1992	-0.010	-0.036	-0.033	0.023
1993	-0.782	-0.838	-0.780	-0.002
1994	0.704	0.681	0.628	0.076
1995	0.412	0.386	0.353	0.059
1996	-1.748	-1.934	-1.761	0.013
1997	-0.352	-0.465	-0.419	0.066
1998	-0.912	-1.014	-0.907	-0.005
1999	0.011	-0.004	-0.004	0.015
2000	-0.318	-0.516	-0.450	0.132
2001	-0.542	-0.603	-0.529	-0.013
2002	-0.709	-0.817	-0.722	0.013
2003	-0.652	-0.722	-0.641	-0.011
2004	-0.562	-0.671	-0.593	0.031
Average	-0.292	-0.367	-0.327	0.035

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

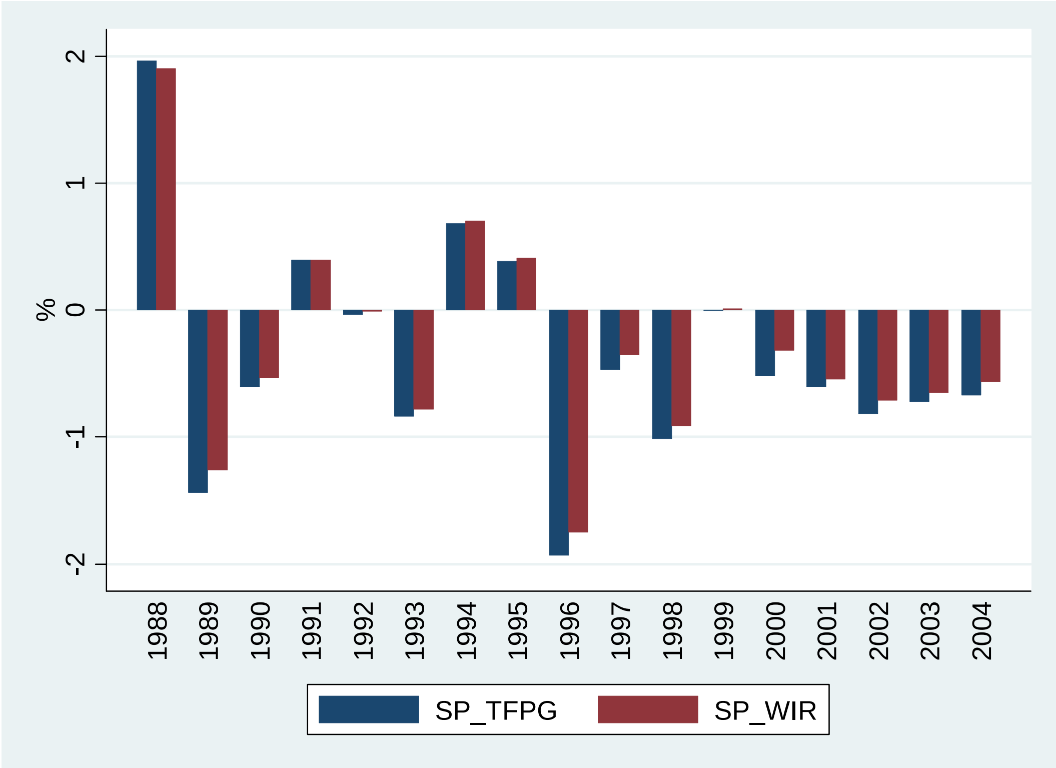
Table A2.12 presents the annual average estimates across three different periods. Both sets of estimates report a positive rate for the first half of the 1990s and a negative rate for the latest periods. The average annual welfare innovation rate is lower than the TFP growth rate when this is negative. As we can observe, the differences between the two series is greatest in the first half of the nineties. These results can be appreciated in Figure A2.8, which presents graphically i(t) and GTFP over the period 1988 to 2004. One can observe that i(t) is less volatile than GTFP.

Table A2.12: Average Annual Growth Rates (Spain)

	1991-1995	1996-2000	2001-2004
I(t)	0.144	-0.664	-0.616
GTFP	0.117	-0.787	-0.703

Notes: GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. i(t) is the Welfare innovation rate obtained from equation 14.

Figure A2.8: i(t) and GTFP, Spain



Source: Authors' calculations and EUKLEMS dataset. SP_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. SP_WIR is the Welfare innovation rate obtained from equation 14.

The US

Finally, data for the US is presented in Table A2.13. The welfare innovation rate is only available for the period 1990 to 2004, as a result of missing data on bilateral imports for earlier years. For the period 1990 to 2004, i(t) is slightly lower than GTFP (0.82%). On average, the percentage contribution to i(t) from non exported home production is 98.1% while the percentage contribution from imports is just 1.9%. The US and Japan are the two countries in the sample with the lowest contribution of imports to the welfare innovation rate.

Table A2.13: i(t), its component parts, and GTFP: US, 1990 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1988	.	1.503	1.423	.
1989	.	-0.269	-0.255	.
1990	-0.464	-0.509	-0.482	0.017
1991	-0.216	-0.235	-0.223	0.006
1992	1.658	1.749	1.657	0.001
1993	-0.566	-0.602	-0.570	0.004
1994	1.334	1.384	1.305	0.029
1995	-0.480	-0.535	-0.503	0.023
1996	0.388	0.397	0.373	0.016
1997	0.538	0.526	0.492	0.046
1998	-0.205	-0.215	-0.202	-0.003
1999	1.663	1.753	1.637	0.026
2000	1.697	1.776	1.645	0.052
2001	0.279	0.305	0.285	-0.005
2002	2.387	2.548	2.379	0.008
2003	1.938	2.082	1.940	-0.002
2004	1.800	1.931	1.787	0.013
Average*	0.783	0.824	0.768	0.015

Notes: Average obtained for the period 1990-2004.
Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

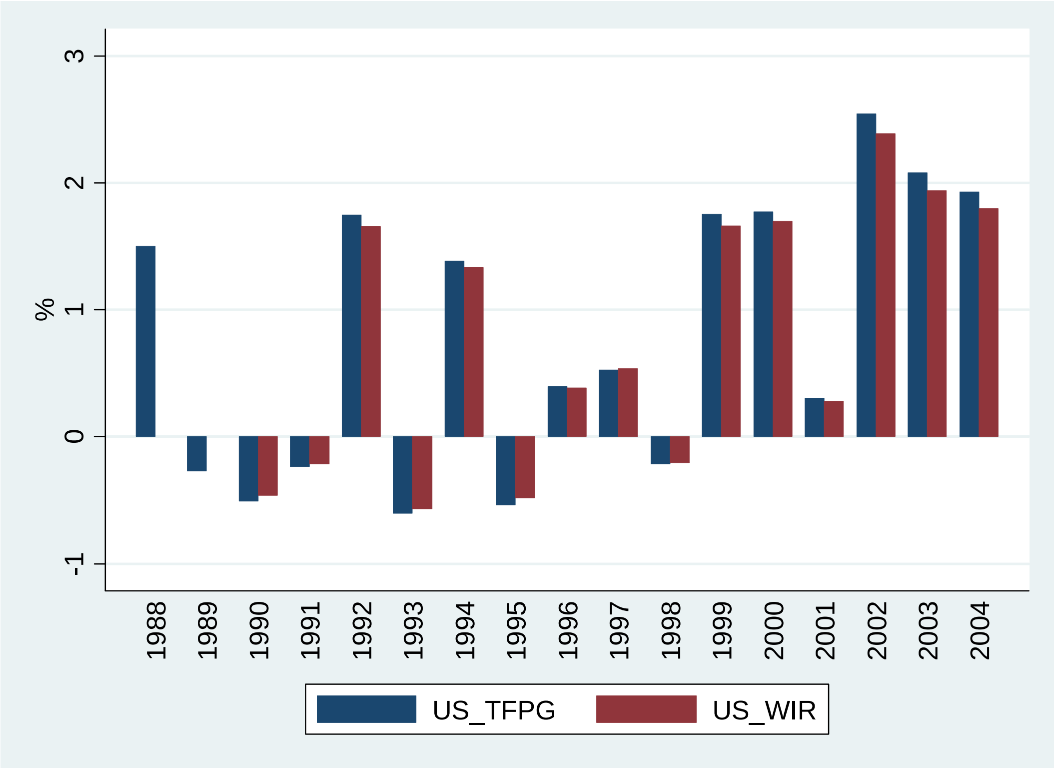
Table A2.14 presents the annual average estimates across three different periods. Despite the mean values for the period 1990 to 2004 being similar, there are significant discrepancies across different periods. The difference between i(t) and GTFP is quite noticeable in the period 2001 to 2004. These results can be better appreciated in Figure A2.9, which presents graphically i(t) and GTFP for the US over the period 1990 to 2004. One can observe, that i(t) is less volatile than GTFP growth rate.

Table A2.14: Average Annual Growth Rates (US)

	1991-1995	1996-2000	2001-2004
US_WIR	0.338	0.777	1.461
US_GTFP	0.352	0.847	1.717

Notes: US_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. i(t) is the Welfare innovation rate obtained from equation 14.

Figure A2.9: Growth Rates, i(t) and GTFP , US



Source: Authors' calculations and EUKLEMS dataset. US_GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. US_WIR is the Welfare innovation rate obtained from equation 14.

APPENDIX 3: UK MANUFACTURING ESTIMATES, THE DETAIL

Manufacturing

Table A3.1 lays out the basic data for UK Manufacturing industry. We observe very similar estimates of i(t) and $\lambda_h(t)$ over the period 1988-2004. From Table A3.1, we obtain that the percentage of the total contribution of innovation to welfare in manufacturing arising from innovation in imported goods is 89%. This contribution significantly contrasts with the 16.5% contribution of imported innovation obtained from the aggregate economy.

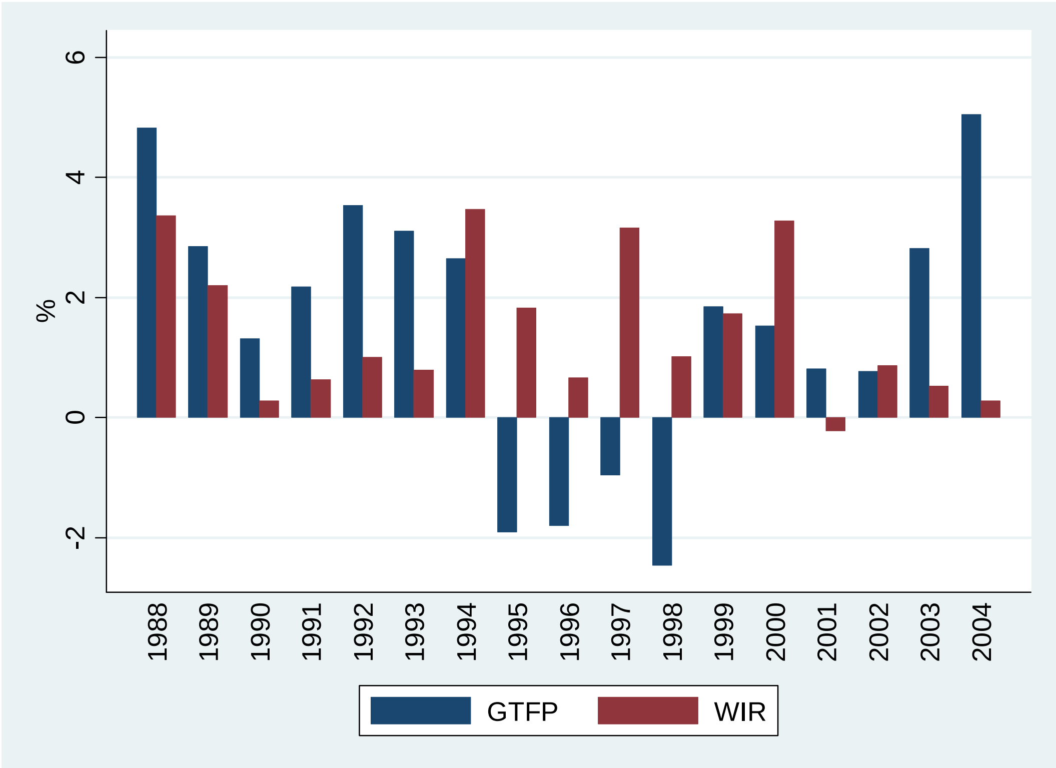
Table A3.1: i(t), its component parts, and GTFP: UK Total Manufacturing, 1988– 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1988	3.364	4.823	2.076	1.288
1989	2.201	2.855	1.146	1.055
1990	0.278	1.314	0.437	-0.159
1991	0.633	2.182	0.645	-0.012
1992	1.009	3.530	0.956	0.053
1993	0.787	3.106	0.629	0.158
1994	3.467	2.651	0.338	3.129
1995	1.824	-1.905	0.158	1.666
1996	0.659	-1.806	0.171	0.488
1997	3.159	-0.954	0.104	3.054
1998	1.019	-2.459	0.070	0.948
1999	1.735	1.847	-0.062	1.797
2000	3.280	1.528	-0.443	3.723
2001	-0.220	0.818	-0.268	0.048
2002	0.868	0.771	-0.262	1.130
2003	0.527	2.823	-1.065	1.592
2004	0.280	5.047	-1.912	2.191
Average	1.463	1.539	0.160	1.303

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

Figure A3.1 presents graphically i(t) and GTFP over the period 1998 to 2004. In contrast to the aggregate case, we observe clear differences between the two series over the analyzed period. The major differences between are observed in the second half of the 1990s, where i(t) is positive while GTFP growth is significantly negative.

Figure A3.1: Growth Rates, i(t) and GTFP, UK Manufacturing



Source: Authors' calculations and EUKLEMS dataset. GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. WIR is the Welfare innovation rate obtained from equation 14.

Food, Beverages and Tobacco

Data for the Food, Beverage and Tobacco industry is presented in Table A3.2. While the average annual rate of TFP growth is negative, the estimate of i(t) is positive at 0.05%. From Table A3.2, we observe that the positive contribution of innovation to the growth in welfare arising from innovation in imported food outweighs the negative contribution arising from innovation in the non exported home production of food, beverages and tobacco.

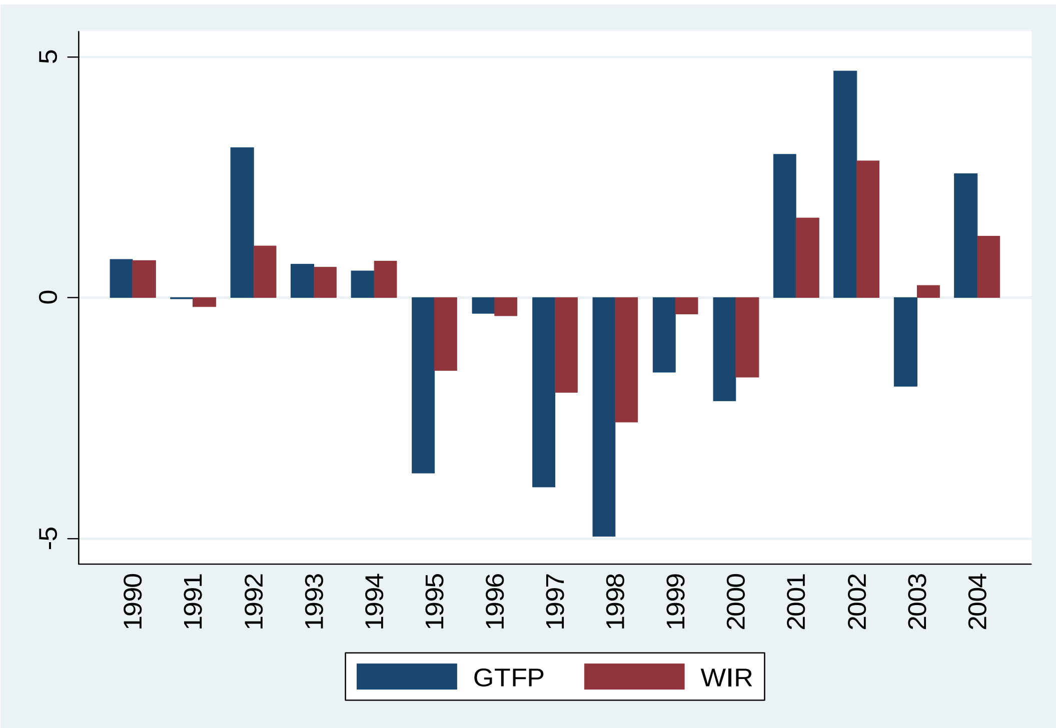
On the other hand, Figure A3.2 presents graphically the estimates of i(t) and GTFP , 1998 to 2004 for the industry. We observe clear differences between the two series over the analyzed period, with i(t) also being less erratic than GTFP.

Table A3.2: The contribution of innovation to welfare, its component parts, and GTFP: UK Food, Beverage and Tobacco industry, 1990 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1990	0.779	0.801	0.481	0.298
1991	-0.180	-0.018	-0.011	-0.169
1992	1.072	3.122	1.819	-0.747
1993	0.630	0.699	0.393	0.237
1994	0.765	0.563	0.299	0.466
1995	-1.505	-3.637	-1.704	0.199
1996	-0.376	-0.328	-0.158	-0.218
1997	-1.969	-3.930	-1.979	0.010
1998	-2.579	-4.956	-2.558	-0.021
1999	-0.334	-1.544	-0.796	0.462
2000	-1.643	-2.145	-1.110	-0.533
2001	1.660	2.975	1.570	0.090
2002	2.847	4.703	2.409	0.438
2003	0.250	-1.840	-0.891	1.141
2004	1.272	2.583	1.265	0.007
Average	0.046	-0.197	-0.065	0.111

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

Figure A3.2: Growth Rates, i(t) and GTFP in the Food, Beverages and Tobacco industry



Source: Authors' calculations and EUKLEMS dataset. GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. WIR is the Welfare innovation rate obtained from equation 14.

Textiles

Data for the Textile industry is presented in Table A3.3. There are significant differences between the estimates of i(t) and GTFP over the 1990-2004 period. While average GTFP is equal to 1.43%, the average of i(t) is 0.57%. From Table A3.3, we observe that the contribution of innovation to welfare arising from innovation in non exported home production is equal to 0.11%, while the contribution from imports, is also positive but much larger at 0.45%.

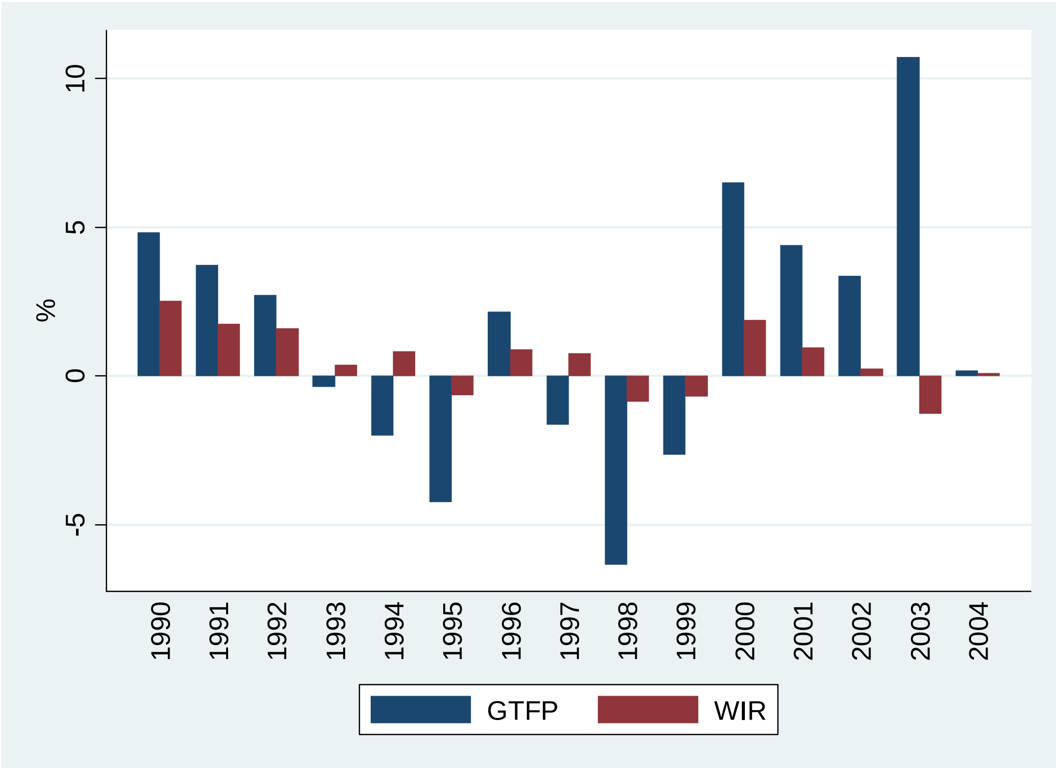
Figure A3.3 presents graphically i(t) and GTFP, 1990 to 2004 for the textile industry. We observe clear differences between the two series over the analyzed period, particularly in the first half of the 2000s. Once more the welfare innovation rate is less erratic than the annual average growth rate of TFP.

Table A3.3: i(t), its component parts, and GTFP: UK Textiles, 1990 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1990	2.520	4.827	2.030	0.490
1991	1.753	3.719	1.457	0.297
1992	1.607	2.715	1.002	0.605
1993	0.377	-0.346	-0.109	0.486
1994	0.821	-1.989	-0.497	1.318
1995	-0.625	-4.217	-0.883	0.258
1996	0.885	2.161	0.395	0.490
1997	0.769	-1.630	-0.367	1.136
1998	-0.850	-6.318	-1.299	0.448
1999	-0.686	-2.631	-0.496	-0.190
2000	1.870	6.494	0.900	0.970
2001	0.960	4.394	0.404	0.556
2002	0.245	3.350	0.122	0.122
2003	-1.267	10.708	-0.961	-0.306
2004	0.103	0.179	-0.033	0.136
Average	0.565	1.428	0.111	0.454

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. i(t) is the Welfare innovation rate obtained from equation 14.

Figure A3.3: Growth Rates, i(t) and GTFP, the Textile industry



Source: Authors' calculations and EUKLEMS dataset. GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. WIR is the Welfare innovation rate obtained from equation 14.

Wood and Wood Products

Data for the Wood industry is presented in Table A3.4. The differences between the estimates of i(t) and GTFP are minor with the average annual rate of TFP growth being -1.01% and the estimated welfare innovation rate being -0.74%. In this case we observe that the contribution of innovation to welfare arising from imports compensates partly for the losses in welfare arising from innovation in the non-exported production.

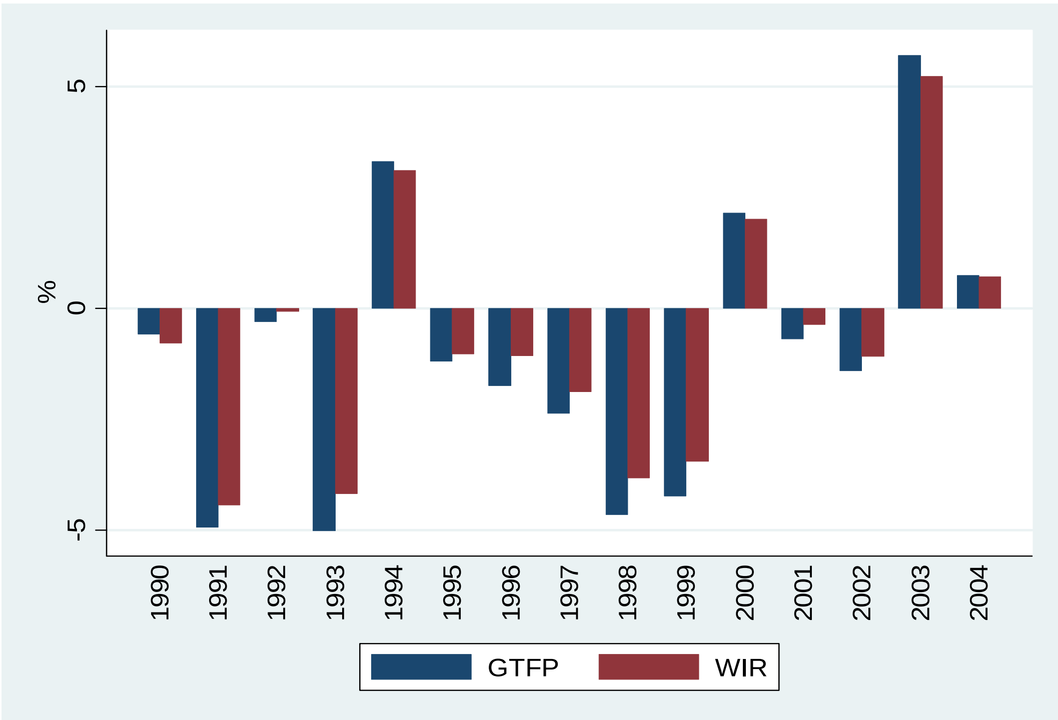
In Figure A3.4 the differences between the two indices are represented graphically. We observe that i(t) and GTFP behave very similarly, although the welfare innovation rate is less volatile than the annual average growth rate of TFP.

Table A3.4: i(t), its component parts, and GTFP: UK Wood and Wood Products, 1990 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1990	-0.783	-0.580	-0.499	-0.284
1991	-4.434	-4.929	-4.310	-0.123
1992	-0.067	-0.296	-0.259	0.192
1993	-4.171	-5.004	-4.262	0.091
1994	3.108	3.312	2.782	0.325
1995	-1.026	-1.181	-1.017	-0.009
1996	-1.072	-1.745	-1.503	0.431
1997	-1.880	-2.368	-2.058	0.178
1998	-3.818	-4.643	-4.088	0.270
1999	-3.436	-4.233	-3.687	0.251
2000	2.012	2.144	1.856	0.157
2001	-0.359	-0.691	-0.598	0.239
2002	-1.082	-1.406	-1.215	0.133
2003	5.232	5.700	4.923	0.308
2004	0.712	0.749	0.652	0.060
Average	-0.738	-1.011	-0.886	0.148

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

Figure A3.4: Growth Rates, i(t) and GTFP in the Wood industry



Source: Authors' calculations and EUKLEMS dataset. GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. WIR is the Welfare innovation rate obtained from equation 14.

Pulp, paper, paper products, printing and publishing industry

Table A3.5 lays out the basic data for Pulp, paper, paper products, printing and publishing over the period 1990 to 2004. Once more the mean i(t) and GTFP measures yield very similar estimates. As in the case of the wood industry, we observe that the contribution of innovation to welfare arising from imports compensates partly for the losses in welfare arising from innovation in the non-exported production.

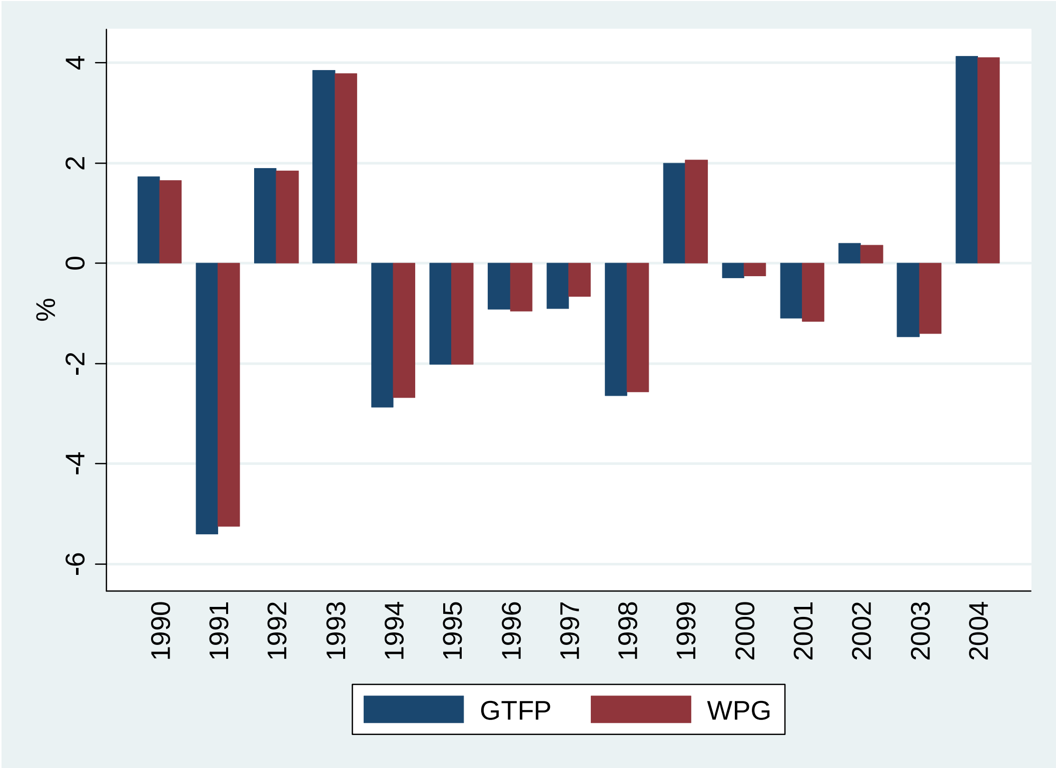
Figure A3.5 graphically shows the differences over time between i(t) and GTFP. As in the wood industry, we observe that the two series behave almost identically.

Table A3.5: i(t), its component parts, and GTFP: UK Pulp, paper, paper products, printing and publishing, 1990 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1990	1.650	1.721	1.655	-0.005
1991	-5.249	-5.400	-5.208	-0.041
1992	1.848	1.889	1.828	0.020
1993	3.780	3.848	3.724	0.056
1994	-2.684	-2.875	-2.778	0.093
1995	-2.020	-2.018	-1.941	-0.079
1996	-0.962	-0.924	-0.891	-0.072
1997	-0.669	-0.906	-0.876	0.207
1998	-2.569	-2.639	-2.556	-0.012
1999	2.053	2.000	1.941	0.112
2000	-0.260	-0.293	-0.284	0.024
2001	-1.158	-1.102	-1.066	-0.092
2002	0.359	0.393	0.381	-0.021
2003	-1.399	-1.469	-1.420	0.020
2004	4.107	4.130	3.993	0.114
Average	-0.212	-0.243	-0.233	0.022

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

Figure A3.5: Growth Rates of the Welfare Innovation rate and TFP in the Pulp, paper, paper products, printing and publishing industry



Source: Authors' calculations and EUKLEMS dataset. GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. WIR is the Welfare innovation rate obtained from equation 14.

Chemical, rubber, plastics and fuel products

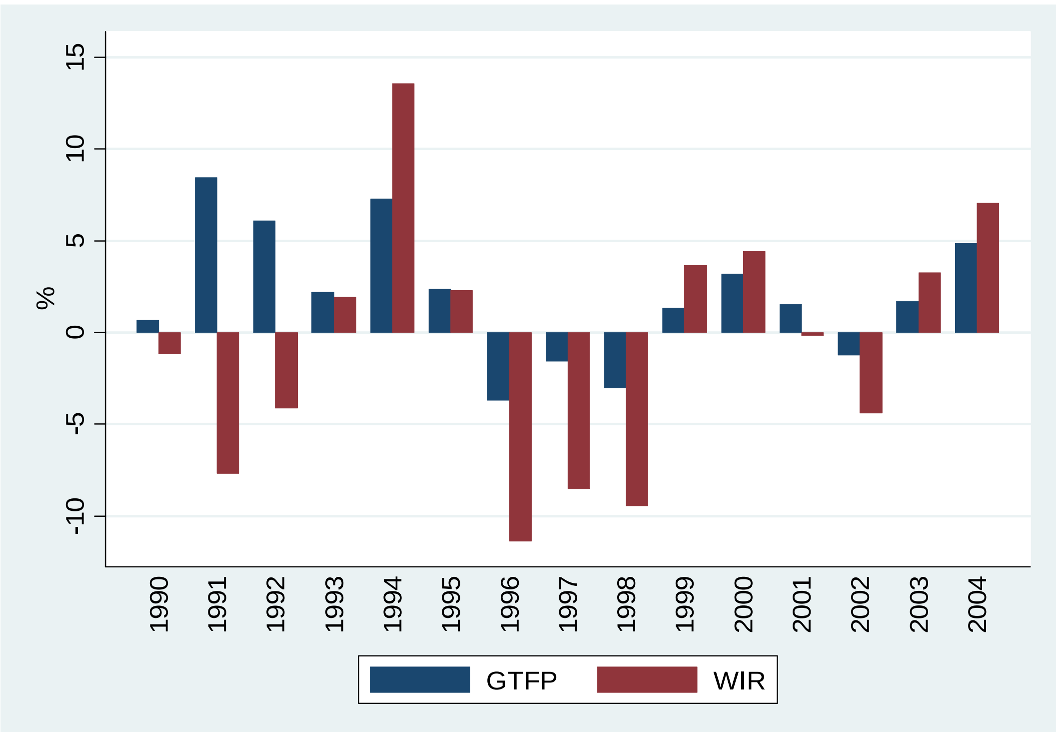
Data for the chemical, rubber, plastics and fuel products industry over the period 1990 to 2004 is presented in Table A3.6. The chemical industry is the sector where the difference between the means of i(t) and GTFP is the largest. In particular, the average annual growth rate of TFP is an estimated 2.01%, while the average of i(t) is -0.71%. From Table A3.6 we also observe that, on average, the contribution of innovation to welfare arising from imports is negative and offsets the positive welfare gains arising from innovation in non-exported production. Figure A3.6 graphically shows the differences over time between i(t) and GTFP, with the biggest disparities arising during the 1990s.

Table A3.6: i(t), its component parts, and GTFP: UK Chemical, rubber, plastics and fuel products, 1990 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1990	-1.162	0.670	-0.270	-0.891
1991	-7.686	8.431	-8.448	0.761
1992	-4.117	6.071	-5.825	1.708
1993	1.936	2.202	5.859	-3.923
1994	13.565	7.270	27.213	-13.649
1995	2.288	2.364	9.966	-7.677
1996	-11.362	-3.680	-8.985	-2.377
1997	-8.499	-1.564	-3.675	-4.823
1998	-9.439	-3.033	-11.782	2.343
1999	3.647	1.344	3.559	0.087
2000	4.439	3.181	5.324	-0.885
2001	-0.166	1.540	2.672	-2.839
2002	-4.388	-1.228	-2.053	-2.335
2003	3.260	1.682	2.503	0.757
2004	7.044	4.841	7.277	-0.233
Average	-0.709	2.006	1.556	-2.265

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

Figure A3.6: Growth Rates, i(t) and GTFP in the chemical, rubber, plastics and fuel products industry



Source: Authors' calculations and EUKLEMS dataset. GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. WIR is the Welfare innovation rate obtained from equation 14.

Other non-metallic mineral products

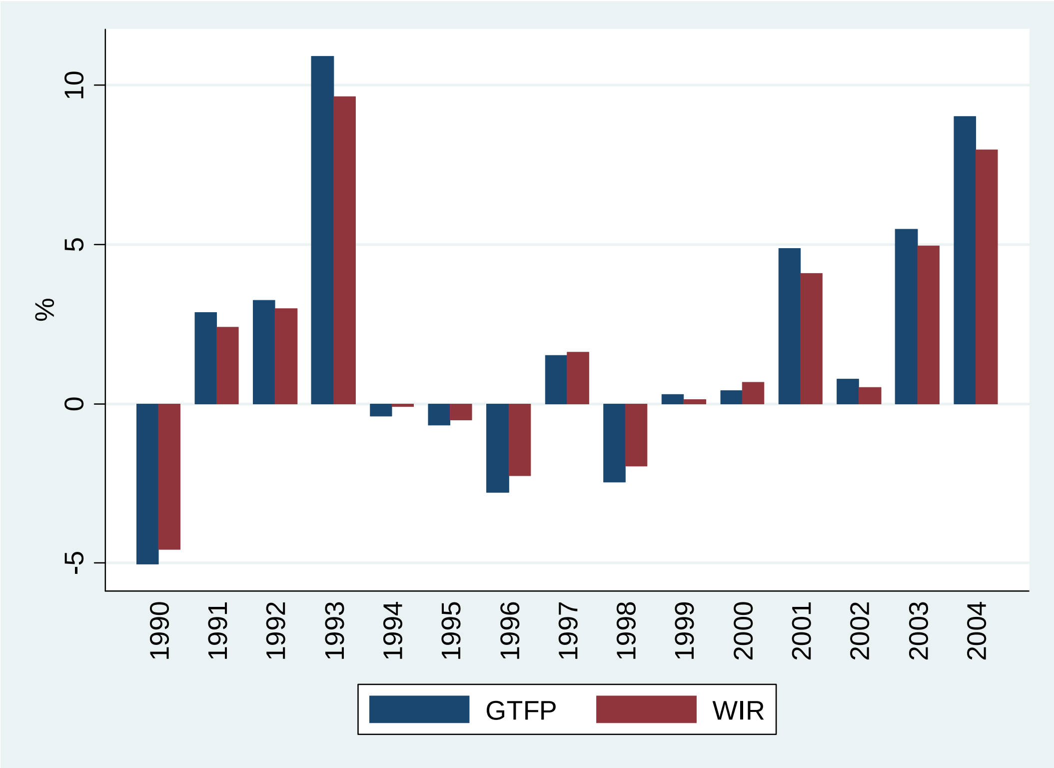
Data for the other non-metallic mineral products industry over the period 1990 to 2004 is presented in Table A3.7. Once more the mean estimates of i(t) and GTFP are very similar. The average annual growth rate of TFP is 1.82% while the average welfare innovation rate is 1.71%. For the mineral industry both the contribution of innovation to welfare arising from imports and that arising from the non-exported production are positive. Figure A3.7 graphically shows that i(t) and GTFP behave very similarly over the period.

Table A3.7: i(t), its component parts, and GTFP: UK other non-metallic mineral products, 1990 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1990	-4.561	-5.022	-4.508	-0.053
1991	2.413	2.871	2.549	-0.136
1992	2.987	3.246	2.849	0.138
1993	9.651	10.916	9.594	0.057
1994	-0.084	-0.392	-0.350	0.266
1995	-0.514	-0.676	-0.603	0.089
1996	-2.254	-2.787	-2.455	0.201
1997	1.630	1.522	1.340	0.290
1998	-1.963	-2.465	-2.162	0.199
1999	0.143	0.291	0.256	-0.113
2000	0.689	0.410	0.356	0.333
2001	4.102	4.879	4.242	-0.139
2002	0.519	0.782	0.682	-0.164
2003	4.961	5.485	4.727	0.234
2004	7.985	9.016	7.725	0.260
Average	1.714	1.872	1.616	0.097

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

Figure A3.7: Growth rates, i(t) and GTFP in the other non-metallic mineral products industry



Source: Authors' calculations and EUKLEMS dataset. GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. WIR is the Welfare innovation rate obtained from equation 14.

Basic metals and fabricated metal products

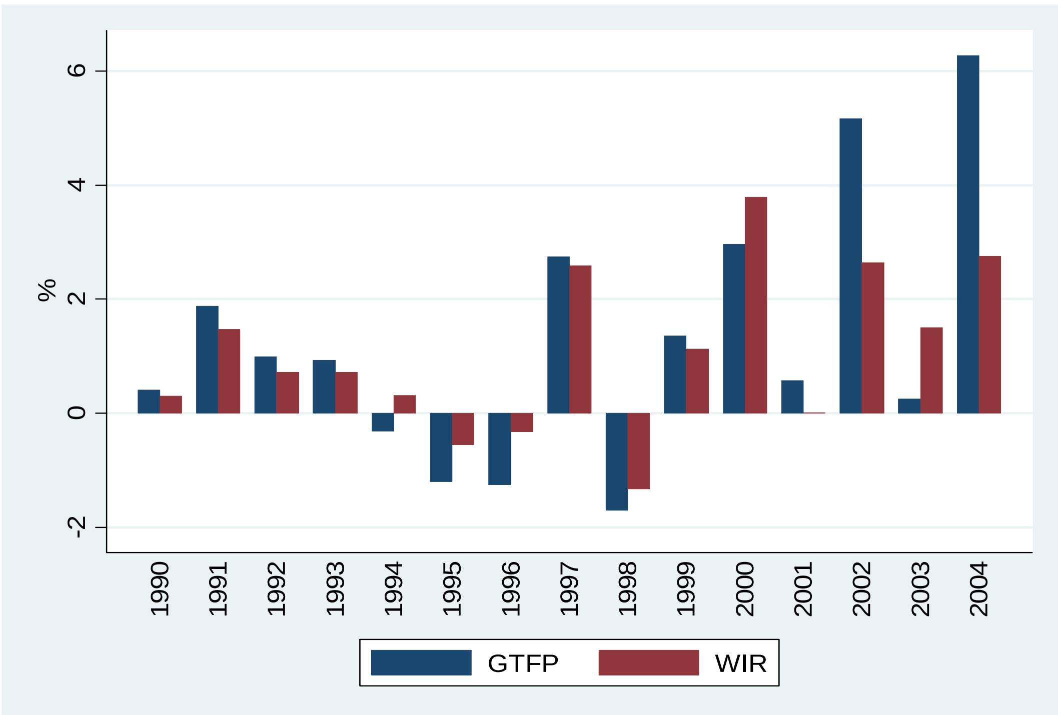
Table A3.8 lays out the data for basic metals and fabricated metal products over the period 1990 to 2004. As for the previous case, the difference between the estimated annual average growth rate of TFP (1.27%) and the welfare innovation ratio (1.05%) is small. For the metal industry both the contribution of innovation to welfare arising from imports and that arising from the non-exported production are positive. Additionally, Figure A3.8 shows graphically the differences over time between i(t) and GTFP, with the largest disparities being seen during the first half of the 2000s.

Table A3.8: The contribution of innovation to welfare, its component parts, and GTFP: UK Basic metals and fabricated metal products, 1990 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1990	0.308	0.404	0.308	0.000
1991	1.469	1.875	1.413	0.056
1992	0.721	0.990	0.763	-0.042
1993	0.723	0.931	0.686	0.037
1994	0.315	-0.312	-0.225	0.540
1995	-0.551	-1.196	-0.803	0.252
1996	-0.321	-1.252	-0.863	0.542
1997	2.591	2.745	2.015	0.576
1998	-1.325	-1.699	-1.300	-0.025
1999	1.128	1.353	1.067	0.061
2000	3.788	2.960	2.014	1.774
2001	-0.005	0.575	0.371	-0.376
2002	2.639	5.169	3.371	-0.732
2003	1.507	0.251	0.144	1.363
2004	2.754	6.274	2.110	0.644
Average	1.049	1.271	0.738	0.311

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

Figure A3.8: Growth Rates, i(t) and GTFP in the Basic metals and fabricated metal products industry



Source: Authors' calculations and EUKLEMS dataset. GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. WIR is the Welfare innovation rate obtained from equation 14.

Machinery and equipment n.e.c

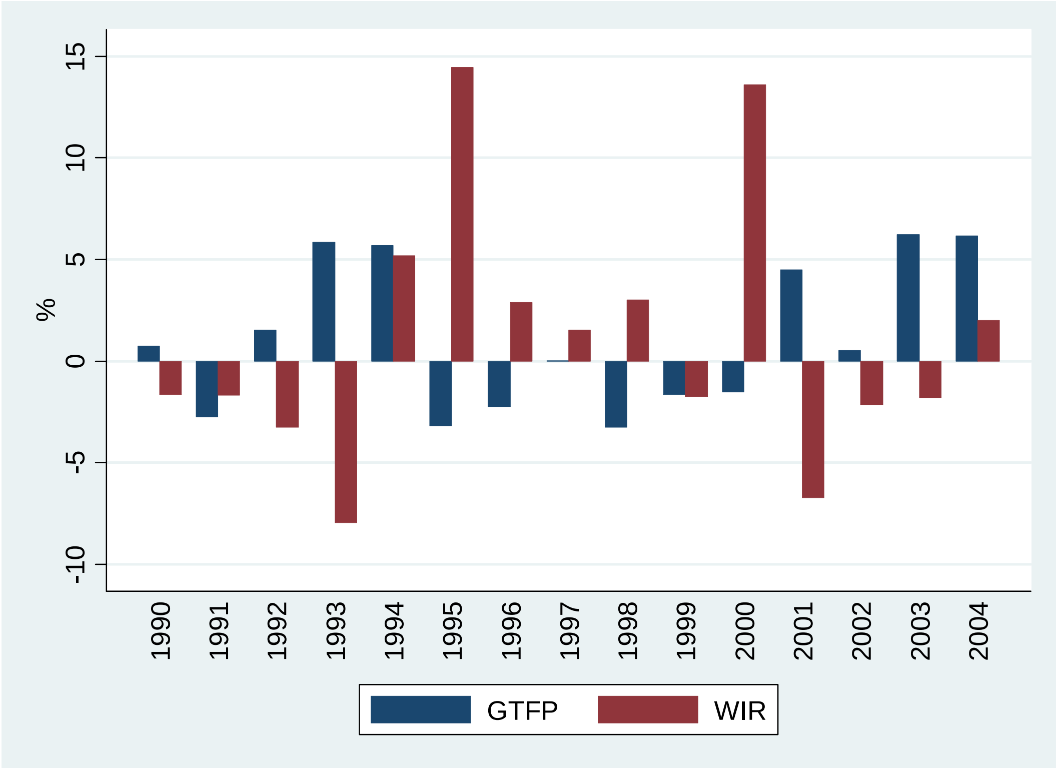
Table A3.9 lays out the basic data for machinery and equipment n.e.c over the period 1990 to 2004. The difference between the estimated annual average growth rate of TFP (1.11%) and i(t) (1.05%) is small. For the machinery industry, on average, the contribution of innovation to welfare arising from imports compensates for losses in welfare arising from innovation in non-exported production. Figure A3.9 shows graphically the differences over time between i(t) and GTFP. Although there is not much difference with respect to the mean estimates, the differences between the two indices over time are significant, being largest during the second half on the 1990s.

Table A3.9: i(t), its component parts, and GTFP: UK Machinery and equipment n.e.c., 1990 – 2004 (% p.a.)

Year	**i(t)**	**$\lambda_h(t)$**	**$\lambda_h(t)\alpha_h(t)$**	**$\Sigma_j(\lambda_j(t)\alpha_j(t))$**
1990	-1.655	0.748	-0.302	-1.353
1991	-1.684	-2.761	1.391	-3.074
1992	-3.272	1.524	-0.844	-2.428
1993	-7.971	5.855	-5.321	-2.650
1994	5.190	5.703	-3.835	9.025
1995	14.460	-3.212	3.094	11.366
1996	2.878	-2.251	3.822	-0.943
1997	1.538	-0.023	0.030	1.508
1998	3.021	-3.249	3.496	-0.475
1999	-1.737	-1.656	1.197	-2.934
2000	13.597	-1.529	1.436	12.161
2001	-6.731	4.486	-3.974	-2.757
2002	-2.169	0.528	-0.368	-1.800
2003	-1.802	6.234	-6.080	4.279
2004	2.005	6.179	-6.215	8.220
Average	1.045	1.105	-0.832	1.876

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

Figure A3.9: Growth Rates, i(t) and TFP, Machinery and equipment n.e.c..



Source: Authors' calculations and EUKLEMS dataset. GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. WIR is the Welfare innovation rate obtained from equation 14.

Electrical and optical equipment

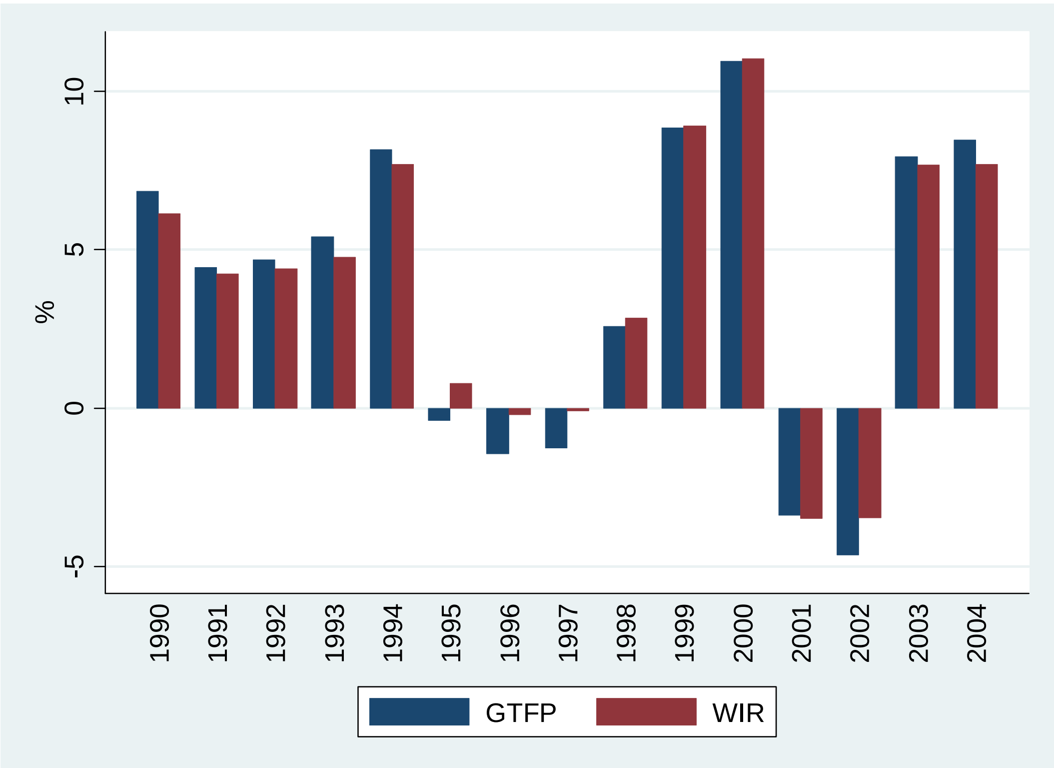
Table A3.10 lays out the basic data for the electrical and optical equipment industry over the period 1990 to 2004. Although having one of the highest average growth rates, the difference between the estimated annual average growth rate of TFP (3.93%) and i(t) (3.82%) is very small. For the electrical industry both the contribution of innovation to welfare arising from imports and that arising from the non-exported production are positive. Figure A3.10 shows graphically that i(t) and GTFP behave very similarly over the sample period.

Table A3.10: i(t), its component parts, and GTFP: UK Electrical and optical equipment, 1990 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1990	6.146	6.860	5.815	0.331
1991	4.237	4.437	3.767	0.470
1992	4.393	4.690	3.887	0.506
1993	4.759	5.419	4.390	0.369
1994	7.702	8.157	6.546	1.156
1995	0.786	-0.390	-0.305	1.091
1996	-0.208	-1.437	-1.104	0.896
1997	-0.100	-1.260	-0.984	0.884
1998	2.849	2.584	2.030	0.819
1999	8.924	8.849	6.956	1.968
2000	11.042	10.953	8.213	2.829
2001	-3.490	-3.399	-2.522	-0.968
2002	-3.472	-4.651	-3.416	-0.056
2003	7.689	7.938	5.522	2.167
2004	7.705	8.480	5.715	1.990
Average	3.931	3.815	2.967	0.963

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

Figure A3.10: Growth Rates, i(t) and GTFP, Electrical and optical equipment .



Source: Authors' calculations and EUKLEMS dataset. GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. WIR is the Welfare innovation rate obtained from equation 14.

Manufacturing n.e.c.

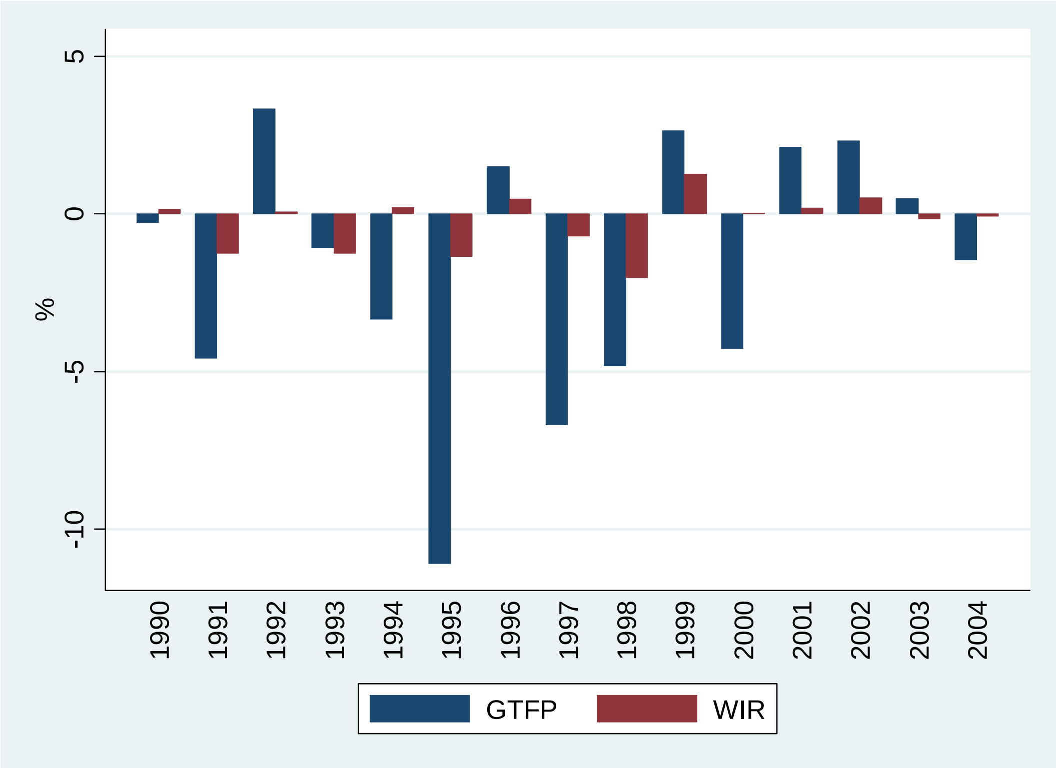
Finally, Table A3.11 lays out the basic data for the manufacturing n.e.c. over the period 1990 to 2004. In this case, the difference between the estimated annual average growth rate of TFP (-1.68%) and the welfare innovation ratio (-0.26%) is quite significant. For this industry the contribution of innovation to welfare arising from imports compensates to a great extent for the loss arising from the non-exported production. Figure A3.11 graphically shows i(t) and GTFP over the period. The differences between i(t) and GTFP are remarkably significant, particularly during the second half of the 1995s. Once more, the welfare innovation rate is less volatile than the growth accounting TFP estimate.

Table A3.11: i(t) , its component parts, and GTFP: UK Manufacturing nec, 1990 – 2004 (% p.a.)

Year	i(t)	$\lambda_h(t)$	$\lambda_h(t)\alpha_h(t)$	$\Sigma_j(\lambda_j(t)\alpha_j(t))$
1990	0.149	-0.272	-0.072	0.221
1991	-1.248	-4.585	-1.072	-0.175
1992	0.059	3.338	0.811	-0.752
1993	-1.258	-1.069	-0.252	-1.006
1994	0.205	-3.352	-0.723	0.928
1995	-1.343	-11.086	-2.746	1.403
1996	0.468	1.508	0.378	0.090
1997	-0.713	-6.683	-1.800	1.087
1998	-2.027	-4.818	-1.526	-0.500
1999	1.268	2.644	0.890	0.378
2000	0.024	-4.276	-1.391	1.416
2001	0.194	2.111	0.636	-0.442
2002	0.512	2.320	0.604	-0.092
2003	-0.149	0.494	0.110	-0.258
2004	-0.083	-1.452	-0.325	0.242
Average	-0.263	-1.678	-0.432	0.169

Source: Authors' calculations and EUKLEMS dataset. $\lambda_h(t)$ is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. **i(t)** is the Welfare innovation rate obtained from equation 14.

Figure A3.11: Growth Rates, i(t) and GTFP in manufacturing nec.



Source: Authors' calculations and EUKLEMS dataset. GTFP is the growth rate of TFP based on Value Added reported by the EUKLEMS dataset. WIR is the Welfare innovation rate obtained from equation 14.