**Employment, Labor Productivity and Technical Progress in the Intimo Model**

by

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## 1 Introduction

The labor productivity equations currently used in the Intimo model[2] express labor productivity (for each sector of the economy) as a function of output or its rate of growth and of a time trend. The ultimate aim of the research described in this paper is to change these equations in order to model the effects of capital investment on labor productivity and employment.

The line of research which is currently undertaken in order to achieve this aim is to introduce the hypothesis that technical progress is also due to improvements in the productivity of new investment goods (i.e that technical progress is embodied in investment goods).

This hypothesis allows us to model some remarkable phenomenons:

*i)* the fact that the most recent investments are more productive than the older, and therefore, for instance, that the physical capital contribution to the productive process increases just thanks to the replacement investment.

ii) the fact that technical progress effects are (at least in part) endogenous, and therefore, for instance, that economic policies can affect labor productivity also through their effects on technical progress diffusion (through their influence on investments).

More precisely our goal is to use a measure of capital stock adjusted to account for embodied technical change as a determinant of labor productivity.

In order to construct such capital stock we need to estimate the rate of embodied technical change.

Unfortunately, estimating the rates of the two components of technical progress is not an easy task. In fact, one result that is widely accepted is that it is impossible to get a reliable direct estimation of the rates of embodied and disembodied technical progress using merely time series data on input and output of a single firm, sector or of the aggregate economy (Gort, Bahk, and Wall, 1993).

Rather what we can estimate are several pairs of rates of the two components of

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[2]Intimo (Interindustry Italian Model) is the Italian member of the Inforum system of multisectoral models. A formal representation of its structure (and of any standard Inforum multisectoral model) is given by its builder in Grassini (2001).

technological change that are equivalent in terms of fit and plausibility. In other words, there is a sort of indeterminacy in describing the growth process: we can read it both as a "mainly disembodied" and as a "mainly embodied" story (see Jorgenson, 1966 and Hall, 1968 for a general description of this problem).

One approach to the estimation of embodied technical change that is plagued by this problem of indeterminacy is the one proposed originally by Solow (1962) and extended by Intriligator (1965)[3].

To get a more reliable direct simultaneous estimation of embodied and disembodied technical progress we need more information than simply the time-series variation. This information can be obtained pooling time series and cross-section data for individual plants (see Gort, Bahk, and Wall, 1993, Mairesse, 1978, Sakellaris and Wilson, 2001, Sung, 1998) or for different countries (see Lee and Kolstad, 1994). The panel structure of the data set allow us to exploit both the time-series and the cross-sectional variation in past investment.

None of these approach can be immediately implemented with reference to the Italian economy.

The micro-data at ISTAT are available only for a very short span of time (from 1992 till 1997). An alternative data bank is at the Bank of Italy and we are currently checking both if we could be allowed to work on it and if it is well suited to our goal.

Implementing the international comparison approach requires that we spend some time collecting data and dealing with the problems of different classification systems and of choosing an appropriate conversion factor. Moreover we think that this second approach is a "second-best" choice with respect to the firm-level data, since it is likely that the cross-sectional variation among different countries is lower than the cross-sectional variation among firms.

On the other hand the Solow-Intriligator's approach mentioned above requires only the series of national accounts, so it's easy to implement.

Though far from ideal, we have decided to apply the Solow-Intriligator's methodology to the Italian sectoral data. The reasons are manifold.

First of all this methodology is a relatively quick and simple way to get some estimations of the two components of technical change that can be used to begin to test what happens when we introduce the embodiment hypothesis in the Intimo model.

Moreover, since our interest in the estimation of the two components of technical change is motivated by the goal of incorporate such estimates in the Intimo model, we think that it is useful to check if the simulation properties of the model are affected by different pairs of rates of technical progress. Only if the simulation properties of the model are affected by the choice of rates of embodied and disembodied technical progress, then it is worth to spend time trying to implement one of the two (time consuming) approaches described above.

Finally we think that checking if different pairs of rates of technical progress give the same simulation results it is an interesting question in its own. For instance, Jorgenson (1966) not only establishes a proposition of observational equivalence between different pairs of rates of technical progress, but also of equivalence in terms of factual implications[4]. Comparing the simulation results with different pairs of the components of technical progress is a way to check

[3]See the final considerations in Intriligator "...there was little significant difference between those regressions including time trend....Thus range estimates are preferable to point estimates".

[4]More precisely, Jorgenson compared a model with only embodied technical progress to a model with only disembodied technical progress and undertook his analysis in an aggregate production function framework.

the validity of this proposition.

In this paper, after a formal definition of the two forms of technical change, we apply the estimation method proposed by Solow to 20 sectors of the Italian economy. Coherently with what we have said above, we find that this approach doesn't give a single estimation of the rates of embodied and disembodied technical change, but rather some pairs that are equivalent in terms of fit and plausibility. Then we describe why the observational equivalence exists. Finally we describe the simulation results of a version of the Intimo model incorporating new labor productivity equations that incorporates a direct influence of capital investment on productivity and employment and we check how the results are affected by different estimates of the rates of embodied and disembodied technical change.

## 2.Definition of embodied and disembodied technical progress

With reference to the way in which technical progress modifies the productivity of production factors, and therefore has economic effect, economists are used to distinguish two different forms of technical progress: embodied and disembodied (in investment goods)[5].

Disembodied technical progress increases the productivity of all production factors, both of those newly created and of those currently existing, and this phenomenon not only arises out of the economy, but also has economic effects independently from what occurs in the economic system: in fact, the expression "manna from heaven" is often used to outline the concept.

In the empirical literature a typical way of modeling disembodied technical progress is that of modeling it as a multiplicative factor that is only a function of time, $e^{\lambda t}$:

$$Q_t = e^{\lambda t} L_t^{(1-\alpha)} K_t^{\alpha} \qquad [1]$$

and of measuring the capital stock as:

$$K_t = \sum_{\tau=0}^{t} (1-\delta)^{t-\tau} I_\tau \qquad [2]$$

where Q is real gross output, L is employment, $\delta$ accounts only for physical decay and real investment, I, must be though as "number of machines".

Note that in this model of technical progress successive vintages of investment goods differ only because of physical decay.

Instead the concept of embodied technical progress is closer to the common idea of technical progress; the point is that the technical progresses have economic effects only when embodied in new investment goods, therefore technological changes need an investment process to influence output and factors productivity: even if technical progress is exogenous, its economic effects (how much manna is picked) depend on what happens in economy.

In order to model this form of technical progress we need to change the definition of capital stock given above (see Hulten, 1992, and Gort and Wall, 1998 for an exhaustive analysis of this

[5]For some recent surveys see Intriligator (1992) e Hercowitz (1998).

point). A model that represents both the embodied and disembodied component of technical progress is the following one:

$$Q_t = e^{\lambda t} L_t^{(1-\alpha)} augK_t^{\alpha} \qquad [3]$$

$$augK_t = \sum_{\tau=0}^{t} (1-\delta)^{t-\tau} augI_\tau = \sum_{\tau=0}^{t} (1-\delta)^{t-\tau} e^{\gamma\tau} I_\tau \qquad [4]$$

where $\gamma$ is the rate of embodied technical change.

Note that in this model successive vintages of investment differ in their efficiency also because they embody technological differences (measured by the term $e^{\gamma t}$).

Note also that if $\gamma=0$ $\forall$t, then augI=I $\forall$t and the two models became identical.

Since the definition of capital stock given in equation [4] is more general than that one in equation [3] in the remainder of this paper when we refer to capital we'll refer to definition [4] above, even if we use the usual notation K instead of augK.

## 2. Solow-Intriligator's approach

Let's assume that in each sector of the economy the technology can be represented by a Cobb-Douglas production function with constant returns to scale and Hicks-neutral disembodied technical change. Moreover we assume that the separability condition holds and that intermediate consumption enter in the production function with a Leontief technology, so that we can get rid of them[6] and we can represent the sector's technology with the equation [3] above

If factors are paid their marginal product then the elasticities $\alpha$ and $(1-\alpha)$ are equal, respectively, to the share of capital and labour in value added.

The basic point in Solow (1962) is to assume that factors are paid their marginal product so that we can treat $\alpha$ as a known coefficient and to treat K as an unknown (since we don't know the parameter $\gamma$).

The way to get an indirect estimation of the rate of embodied technical progress proposed by Solow is to construct several series of K with alternative trial values of $\gamma$, to estimate the corresponding production functions and then choose the value of $\gamma$ by comparing the fit and the plausibility of the estimated factors elasticities (where plausibility means "close to the factor share").

Solow assumed that there is no disembodied technical progress, so actually he didn't try to disentangle the two forms of technical change. Instead Intriligator (1965) allowed for both the embodied and the disembodied form of technical change.

Dividing equation [3] by L on both sides, taking the logs and adding a change in output term (current and lagged one year) to catch the procyclicity of labor productivity we get the estimated

[6] Solow worked at the macro level, so in his model the output concept is GDP and he don't even mention intermediate consumption.

equation[7]:

$$(q_t\text{-}l_t) = a_0 + a_1(k_t\text{-}l_t) + a_2 \text{ time} + a_3 (q_t\text{-}q_{t-1}) + a_4 (q_{t-1}\text{-}q_{t-2}) \qquad [5]$$

where small letters denote natural logs and $a_1=\alpha$ and $a_2=\lambda$.

We tried to apply the Solow-Intriligator approach to equation [5] but we encountered a considerable econometric problem. Modelling embodied technical change by augmenting real investment by an exponential augmentation factor makes the capital stock similar to a time trend, so that there is a high degree of collinearity between the augmented capital-labor ratio and the time trend (and obviously the collinearity is greater the larger is the rate of embodied technical change, $\gamma$).

To deal with this problem we have tried two different modifications:

1) estimating equation [5] constraining the time trend coefficient (i.e. the rate of disembodied technical change) to be equal to various trial values and following the Solow-Intriligator approach for each of these trial values (i.e. trying various capital stock series obtained assuming various rates of embodied technical change and then choosing as an estimate of the rate of embodied technical change the value of $\gamma$ that gives an estimated coefficient of the capital-labor ratio equal to the capital share in value added).

2) estimating equation [5] for various trial values of the rate of embodied technical change constraining the capital-labor coefficient to be equal to the capital share in value added and then choosing the value of $\gamma$ simply by comparing the fit.

Note that both of the approaches might not give a single estimation of the rates of the two forms of technical change. In the first one we could find that more than one pair of (reasonable) rates of embodied and disembodied technical change gives an estimated coefficient of the capital/labor ratio equal to the capital share without any appreciable difference in the fit. In the second approach, the difference in the fit among different pairs of embodied and disembodied technical change could be too small to allow a choice.

Another econometric problem can arise because in equation [5] the variables output and labor appear both on the right and the left-hand side.

To check the robustness of our results we have applied the approach number 2) described above to the following equation, derived taking the logs of equation [3], solving for l (the log of employment) and adding a change in output term (current and lagged one year):

$$l_t = b_0 + b_1 k_t + b_2 q_t + b_3 \text{ time} + b_4 (q_t\text{-}q_{t-1}) + b_5 (q_{t-1}\text{-}q_{t-2}) \qquad [6]$$

where the following relations link the estimated coefficients to the coefficients of the production function [3]: $b_1=(\alpha/\alpha\text{-}1))$, $b_1+b_2=1$ and $b_3=(\lambda/(\alpha\text{-}1))$.

## 3. Estimations results

Table 2 reports the results obtained using the approach 1) described above, while table1 reports, for the years 1983-1998, the average values of the shares of capital in value added at

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[7] These form of the estimated equation differs from the one estimated by Intriligator (1965) only in the way cyclical factors are modelled: Intriligator, like Solow, introduce a function of the unemployment rate as a measure of the cycle.

current prices and the average annual growth of labor productivity (see appendix A for a description of the data we have used and appendix B for a description of how we have computed the capital shares). The trial values for the rate of disembodied technical change are 0%, 1%, 2%, 3% and 4%. The limits of our regressions are 1983-1998. For each of these trial values we report the rate of embodied technical change (if any) that gives an estimated coefficient of the (log of) the capital-labor ratio equal to the capital share (Emb) and two measures of the fit of the corresponding equation: the Standard Error of Estimate (SEE) and the R-square (RSQ). A shaded cell indicate that there's no rate of embodied technical change (zero included) that gives an estimated coefficient of the (log of) the capital-labor ratio equal to the capital share.

The results reported in table 2 are similar to those (not reported here) obtained using the approach 2) both with equation [4] and [5].

Two results are clear: there is a trade-off between the embodied and the disembodied component of technical progress; in all sectors there are two or more pairs of rates of embodied and disembodied technical change that are equivalent in terms of fit.

Table 3 illustrates the "equivalence" more clearly. For each trial value of the rate of disembodied technical change, it reports the percentage difference between the corresponding SEE and the lowest SEE (so a value equal to zero indicate the best fit).

We see that, for instance, if we consider as equivalent in terms of fit a difference of 10 percent in the SEE, then for all sectors we have at least two pairs of rates of embodied and disembodied technical change that are equivalent in terms of fit (and obviously in terms of the estimated coefficient of K/L).

Moreover, in all sectors but three, the SEE monotonically decreases as the assumed rate of disembodied technical change increases.

**Table 1**

| Sectors | Capital Share average 83-98 | Labor Productivity annual growth 83-98 |
|---|---|---|
| 3 Non-energy Minerals Mining | 0.37 | 6.2 |
| 4 Food.Beverages & Tobacco | 0.4 | 2.41 |
| 5 Textiles & Clothing | 0.29 | 3.87 |
| 6 Leather & Leather Products | 0.31 | 4.45 |
| 7 Wood & Wooden Products | 0.27 | 4.79 |
| 8 Paper & Printing Products | 0.3 | 3.32 |
| 10 Chemical Products | 0.42 | 4.08 |
| 11 Rubber & Plastic Products | 0.35 | 2.16 |
| 12 Non-metallic Mineral Products | 0.37 | 2.85 |
| 13 Metal & Metal Products | 0.28 | 4.17 |
| 14 Agric. & Indust. Non-electrical Machinery | 0.31 | 3.64 |
| 15 Electrical&Office Machin.&Communic. Equip. | 0.31 | 4.54 |
| 16 Transport Equipment | 0.21 | 4.79 |
| 17 Other Manufacturing | 0.31 | 2.71 |
| 18 Electricity. Gas & Water | 0.52 | 2.79 |
| 19 Construction | 0.33 | 1.19 |
| 20 Wholesale & Retail Trade & R epair Services | 0.32 | 3 |
| 21 Hotels. Restaurants and Cafes | 0.19 | 0.3 |
| 22 Transports. Storage & Communications | 0.31 | 3.39 |
| 23 Banking. Finance & Insurance | 0.4 | 3.86 |

**Table 2**

| Sectors | Dis=0 | | |
|---|---|---|---|
| | Emb | SEE | RSQ |
| 3 Non-energy Minerals Mining | 14 | 0.043 | 0.973 |
| 4 Food.Beverages & Tobacco | 6 | 0.017 | 0.976 |
| 5 Textiles & Clothing | 14 | 0.022 | 0.986 |
| 6 Leather & Leather Products | 16 | 0.028 | 0.982 |
| 7 Wood & Wooden Products | 19 | 0.031 | 0.978 |
| 8 Paper & Printing Products | 9.5 | 0.033 | 0.954 |
| 10 Chemical Products | 9.5 | 0.042 | 0.943 |
| 11 Rubber & Plastic Products | 7 | 0.022 | 0.938 |
| 12 Non-metallic Mineral Products | 7 | 0.041 | 0.888 |
| 13 Metal & Metal Products | 15.5 | 0.014 | 0.995 |
| 14 Agric. & Indust. Non-electrical Machinery | 11.5 | 0.026 | 0.973 |
| 15 Electrical&Office Machin.&Communic. Equip. | 13.5 | 0.027 | 0.98 |
| 16 Transport Equipment | 17 | 0.056 | 0.917 |
| 17 Other Manufacturing | 9 | 0.03 | 0.928 |
| 18 Electricity. Gas & Water | 5 | 0.04 | 0.913 |
| 19 Construction | 4 | 0.026 | 0.797 |
| 20 Wholesale & Retail Trade & Repair Services | 8.5 | 0.012 | 0.994 |
| 21 Hotels. Restaurants and Cafes | 2 | 0.01 | 0.824 |
| 22 Transports. Storage & Communications | 10 | 0.012 | 0.994 |
| 23 Banking. Finance & Insurance | 10.5 | 0.035 | 0.965 |

| Sectors | Dis=1 | | |
|---|---|---|---|
| | Emb | SEE | RSQ |
| 3 Non-energy Minerals Mining | 12 | 0.044 | 0.973 |
| 4 Food.Beverages & Tobacco | 3 | 0.016 | 0.978 |
| 5 Textiles & Clothing | 10.5 | 0.021 | 0.987 |
| 6 Leather & Leather Products | 13 | 0.026 | 0.985 |
| 7 Wood & Wooden Products | 15.5 | 0.03 | 0.98 |
| 8 Paper & Printing Products | 6 | 0.032 | 0.957 |
| 10 Chemical Products | 7 | 0.042 | 0.944 |
| 11 Rubber & Plastic Products | 4 | 0.02 | 0.949 |
| 12 Non-metallic Mineral Products | 4 | 0.04 | 0.894 |
| 13 Metal & Metal Products | 12 | 0.013 | 0.996 |
| 14 Agric. & Indust. Non-electrical Machinery | 8 | 0.025 | 0.974 |
| 15 Electrical&Office Machin.&Communic. Equip. | 10 | 0.027 | 0.98 |
| 16 Transport Equipment | 12 | 0.056 | 0.918 |
| 17 Other Manufacturing | 5.5 | 0.031 | 0.919 |
| 18 Electricity. Gas & Water | 2.5 | 0.039 | 0.918 |
| 19 Construction | 0 | 0.024 | 0.822 |
| 20 Wholesale & Retail Trade & Repair Services | 5 | 0.011 | 0.994 |
| 21 Hotels. Restaurants and Cafes | | | |
| 22 Transports. Storage & Communications | 6.5 | 0.012 | 0.995 |

| | | | |
|---|---|---|---|
| 23 Banking. Finance & Insurance | 7.5 | 0.033 | 0.969 |

**Table 2 (continued)**

| Sectors | Dis=2 | | |
|---|---|---|---|
| | Emb | SEE | RSQ |
| 3 Non-energy Minerals Mining | 9 | 0.045 | 0.972 |
| 4 Food.Beverages & Tobacco | | | |
| 5 Textiles & Clothing | 7 | 0.019 | 0.989 |
| 6 Leather & Leather Products | 9.5 | 0.023 | 0.988 |
| 7 Wood & Wooden Products | 11 | 0.029 | 0.981 |
| 8 Paper & Printing Products | 2 | 0.031 | 0.96 |
| 10 Chemical Products | 4 | 0.042 | 0.945 |
| 11 Rubber & Plastic Products | | | |
| 12 Non-metallic Mineral Products | | | |
| 13 Metal & Metal Products | 8 | 0.012 | 0.996 |
| 14 Agric. & Indust. Non-electrical Machinery | 4 | 0.024 | 0.975 |
| 15 Electrical&Office Machin.&Communic. Equip. | 6.5 | 0.026 | 0.981 |
| 16 Transport Equipment | 7 | 0.055 | 0.921 |
| 17 Other Manufacturing | 2.5 | 0.037 | 0.889 |
| 18 Electricity. Gas & Water | 0 | 0.038 | 0.921 |
| 19 Construction | | | |
| 20 Wholesale & Retail Trade & Repair Services | 1 | 0.011 | 0.994 |
| 21 Hotels. Restaurants and Cafes | | | |
| 22 Transports. Storage & Communications | 2.5 | 0.011 | 0.995 |
| 23 Banking. Finance & Insurance | 4.5 | 0.031 | 0.973 |

| Sectors | Dis=3 | | |
| --- | --- | --- | --- |
| | Emb | SEE | RSQ |
| 3 Non-energy Minerals Mining | 6 | 0.045 | 0.971 |
| 4 Food.Beverages & Tobacco | | | |
| 5 Textiles & Clothing | 2.5 | 0.018 | 0.99 |
| 6 Leather & Leather Products | 5.5 | 0.021 | 0.99 |
| 7 Wood & Wooden Products | 7 | 0.028 | 0.983 |
| 8 Paper & Printing Products | | | |
| 10 Chemical Products | 0.5 | 0.043 | 0.943 |
| 11 Rubber & Plastic Products | | | |
| 12 Non-metallic Mineral Products | | | |
| 13 Metal & Metal Products | 3.5 | 0.011 | 0.997 |
| 14 Agric. & Indust. Non-electrical Machinery | 0 | 0.024 | 0.976 |
| 15 Electrical&Office Machin.&Communic. Equip. | 2.5 | 0.026 | 0.982 |
| 16 Transport Equipment | 0.5 | 0.054 | 0.923 |
| 17 Other Manufacturing | | | |
| 18 Electricity. Gas & Water | | | |
| 19 Construction | | | |
| 20 Wholesale & Retail Trade & Repair Services | | | |
| 21 Hotels. Restaurants and Cafes | | | |
| 22 Transports. Storage & Communications | | | |
| 23 Banking. Finance & Insurance | 1.5 | 0.029 | 0.976 |

**Table 2 (continued)**

| Sectors | Dis=4 | | |
|---|---|---|---|
| | Emb | SEE | RSQ |
| 3 Non-energy Minerals Mining | 2.5 | 0.045 | 0.971 |
| 4 Food.Beverages & Tobacco | | | |
| 5 Textiles & Clothing | | | |
| 6 Leather & Leather Products | 1 | 0.019 | 0.992 |
| 7 Wood & Wooden Products | 2.5 | 0.027 | 0.984 |
| 8 Paper & Printing Products | | | |
| 10 Chemical Products | | | |
| 11 Rubber & Plastic Products | | | |
| 12 Non-metallic Mineral Products | | | |
| 13 Metal & Metal Products | | | |
| 14 Agric. & Indust. Non-electrical Machinery | | | |
| 15 Electrical&Office Machin.&Communic. Equip. | | | |
| 16 Transport Equipment | | | |
| 17 Other Manufacturing | | | |
| 18 Electricity. Gas & Water | | | |
| 19 Construction | | | |
| 20 Wholesale & Retail Trade & Repair Services | | | |
| 21 Hotels. Restaurants and Cafes | | | |
| 22 Transports. Storage & Communications | | | |
| 23 Banking. Finance & Insurance | | | |

**Table 3**

| Sectors | Dis=0 | Dis=1 | Dis=2 | Dis=3 | Dis=4 |
|---|---|---|---|---|---|
| 3 Non-energy Minerals Mining | 0 | 1.21 | 2.68 | 3.57 | 4.53 |
| 4 Food.Beverages & Tobacco | 5.74 | 0 | | | |
| 5 Textiles & Clothing | 21.74 | 14.47 | 7.51 | 0 | |
| 6 Leather & Leather Products | 46.45 | 34.3 | 21.95 | 9.95 | 0 |
| 7 Wood & Wooden Products | 14.74 | 11.7 | 7.45 | 3.19 | 0 |
| 8 Paper & Printing Products | 7.16 | 3.69 | 0 | | |
| 10 Chemical Products | 1.53 | 0.51 | 0 | 1.95 | |
| 11 Rubber & Plastic Products | 10.52 | 0 | | | |
| 12 Non-metallic Mineral Products | 2.63 | 0 | | | |
| 13 Metal & Metal Products | 22.08 | 14.29 | 6.49 | 0 | |
| 14 Agric. & Indust. Non-electrical Machinery | 6.36 | 4.03 | 1.24 | 0 | |
| 15 Electrical&Office Machin.&Communic. Equip. | 6.79 | 5.02 | 2.69 | 0 | |
| 16 Transport Equipment | 3.87 | 3.04 | 1.28 | 0 | |
| 17 Other Manufacturing | 0 | 5.96 | 24.43 | | |
| 18 Electricity. Gas & Water | 4.75 | 1.93 | 0 | | |
| 19 Construction | 6.75 | 0 | | | |
| 20 Wholesale & Retail Trade & Repair Services | 3.7 | 2.04 | 0 | | |
| 21 Hotels. Restaurants and Cafes | 0 | | | | |
| 22 Transports. Storage & Communications | 7.54 | 3.61 | 0 | | |
| 23 Banking. Finance & Insurance | 22.33 | 14.92 | 7.52 | 0 | |

## 4. Some considerations

The main result from the previous estimations is that we can't find a point estimation for the rates of embodied and disembodied technical change in a pure time series framework: there is a sort of observational equivalence between different pairs of rates of technical change.

Should we be surprised by this results?

The answer is no. This point has been illustrated in a different context, e.g., by Jorgenson (1966) and by Hall (1968).

We are going to illustrate it with reference to our model.

Our basic equation is the standard Cobb-Douglas production function with constant return to scale:

$$\frac{Q}{L} = A\,e^{\lambda t}\left(\frac{K}{L}\right)^{\alpha} \qquad [7]$$

If all variables grew at constant exponential rates we could represent the trend structure of this equation in the following way:

$$\frac{e^{\delta t}}{e^{\mu t}} = e^{\lambda t}\left(\frac{e^{(\gamma+\eta)t}}{e^{\mu t}}\right)^{\alpha} \qquad [8]$$

where $\delta$, $\mu$ and $\eta$ are, respectively, the rates of growth of real gross output, employment and real investments (not adjusted for quality changes) and are observable.

If we assume that $\alpha$ is observable too (as we did in our estimation strategy), then basically our problem is to find $\gamma$ and $\lambda$ such that [8] holds, i.e., such that

$$(\delta + \mu)\, t = (\lambda + \alpha\gamma + \alpha\eta - \alpha\mu)\, t \qquad [8]$$

Obviously there are infinite pairs of $\gamma$'s and $\lambda$'s that satisfies this equation.

Rearranging equation [8] we can characterise the trade-off between $\gamma$ and $\lambda$.

Collecting all the known rates of growth in a constant k, we have the following condition:

$$\alpha\gamma + \lambda = k$$

and we can represent the trade-off between the embodied and the disembodied component with the following linear function:

$$\gamma = k - \left(\frac{1}{\alpha}\right)\lambda \qquad [9]$$

that shows that the trade-off is function only of the elasticity of output with respect to capital.

Obviously real variables do not grow at constant exponential rates, so equation [9] cannot describe exactly our results. Anyway, it gives a good approximation, as we can see in table 4, that reports the value of ($1/\alpha$) and the slope of equation [9] estimated by regressing the estimated $\gamma$'s on the corresponding $\lambda$'s.

**Table 4**

| Sectors | RegLin | 1/α |
|---|---|---|
| 3 Non-energy Minerals Mining | -3 | 2.7 |
| 4 Food.Beverages & Tobacco | -3 | 2.5 |
| 5 Textiles & Clothing | -3.95 | 3.45 |
| 6 Leather & Leather Products | -3.75 | 3.23 |
| 7 Wood & Wooden Products | -4.15 | 3.7 |
| 8 Paper & Printing Products | -3.75 | 3.33 |
| 10 Chemical Products | -3 | 2.38 |
| 11 Rubber & Plastic Products | -3 | 2.86 |
| 12 Non-metallic Mineral Products | -3 | 2.7 |
| 13 Metal & Metal Products | -4 | 3.57 |
| 14 Agric. & Indust. Non-electrical Machinery | -3.85 | 3.23 |
| 15 Electrical & Office Machinery & Communications Equip. | -3.4 | 3.23 |
| 16 Transport Equipment | -5.45 | 4.76 |
| 17 Other Manufacturing | -3.25 | 3.23 |
| 18 Electricity. Gas & Water | -2.5 | 1.92 |
| 19 Construction | -4 | 3.03 |
| 20 Wholesale & Retail Trade & Repair Services | -3.75 | 3.13 |
| 21 Hotels. Restaurants and Cafes | | 5.26 |
| 22 Transports. Storage & Communications | -3.75 | 3.23 |
| 23 Banking. Finance & Insurance | -3 | 2.5 |

## 5. Incorporating the new labor productivity equations into Intimo

In order to model the effects of capital investment on labor productivity and employment into the model, the first issue we need to deal with is choosing what labor productivity equations to use.

Equation [5] above cannot be used directly as labor productivity equations into the model, because employment appears both on the right-hand side and on the left-hand side.

One way to use it would be to modify the model code to solve labor productivity equations by iteration but we have chosen a different option: we decided to use equation [6] above to forecast directly the amount of labor needed to produce output, given the amount of capital.

Though equation [6] forecasts directly the log of employment, we will refer to it as a labor productivity equation because it is obtained rearranging a labor productivity equation and is estimated imposing all the relations that link its coefficients to the coefficients of the labor productivity equation and because its role in the model is the same than the role of labor productivity equations.

A second issue is that the series of investment by purchasers in the model are available only by 21 sectors while the model requires employment by 41 sectors.

To deal with this problem we decided to forecast employment by 21 sectors using equation [6] and then to split the 21 sectors employment to the 41 sectors level using as shares the employment forecasted by the old labor productivity equations.

For instance, if sector 1 at the 21-sector level is split into two sector at the 41-sector level, we split employment computed at the 21-sector level, e[1], to employment at the 41-sector level, emp[1] and emp[2], using the following expressions:

emp[1]=(emp'[1]/(emp'[1]+emp'[2]))*e[1]

emp[2]=(emp'[2]/(emp'[1]+emp'[2]))*e[1]

where emp' is employment forecasted by the old labor productivity equations. The great advantage of this method is that it provides time-varying shares.

The last point we need to mention is that the Intimo's database is not based upon the new Italian national accounts (the data we have used in the previous paragraph), so we couldn't use the estimations of the rates of embodied and disembodied technical change that we have described above (even the classification system is not the same).

The main problem with the Intimo's database is that the series of investment by purchasers is available only for the years 1980 to 1994, so the series of capital stock that we can construct are not very reliable. Indeed this is the reason why in the previous paragraph we have presented the results from the new national accounts.

In order to get the estimates of the rates of the two components of technical change and of the other parameters of equation [6], we applied, for each of the 21 sectors, the method labeled as method number 2) in paragraph two to equation [6].

We decided to use the new equations only for 19 sectors. The sectors excluded are Non tradable services (because of a very bad fit) and Government (because for this sector it's not clear what is the share of capital).

Table 5 reports, for each of the 19 sectors, two pairs of estimates of the rates of embodied and disembodied technical changes, a pair with a high rate of embodied technical change and a low rate of disembodied technical change and labeled as "High Emb", and another one with a high rate of the disembodied component and a low rate of the embodied one (indeed equal to zero in almost all sectors) and labeled as "High Dis".

The two pairs of estimates are equivalent in terms of fit and equivalent to the estimate that gives the best fit: for both of them, the difference of the SEE with respect to the SEE of the estimate that gives the best fit is less or equal to 5 percent.

Another estimation result that it is worth to mention is that in almost all sectors the coefficients of the current and lagged change in output are negative that is what we expected because of the procyclicality of labor productivity.

**Table 5**

| | | embodied | disembod. |
|---|---|---|---|
| 1 Agriculture,Forestry,Fishery | "High Dis" | 12 | 1.5 |
| | "High Emb" | 22 | 0.2 |
| 2 Energy Sectors | "High Dis" | 0 | 1.4 |
| | "High Emb" | 2 | 0.6 |
| 3 Ferrous & Nonferrous Minerals | "High Dis" | 12 | 2.8 |
| | "High Emb" | 22 | 0.2 |
| 4 Non-metallic Mineral Products | "High Dis" | 0 | 3.7 |
| | "High Emb" | 14 | 1.0 |
| 5 Chemical Products | "High Dis" | 0 | 4.7 |
| | "High Emb" | 6 | 3.1 |
| 6 Metal Products | "High Dis" | 0 | 4.6 |
| | "High Emb" | 4 | 3.8 |
| 7 Agric. & Industr. Machinery | "High Dis" | 0 | 3.2 |
| | "High Emb" | 6 | 2.0 |
| 8 Office. Prec. Comput. Instrum. | "High Dis" | 0 | 4.5 |
| | "High Emb" | 20 | 0.3 |
| 9 Electrical Goods | "High Dis" | 0 | 5.9 |
| | "High Emb" | 4 | 5.3 |
| 10 Motor Vehicles | "High Dis" | 0 | 4.3 |
| | "High Emb" | 8 | 2.9 |
| 11 Food & Tobacco Industry | "High Dis" | 0 | 2.3 |
| | "High Emb" | 2 | 1.8 |
| 12 Textile & Leather Goods | "High Dis" | 0 | 3.2 |
| | "High Emb" | 10 | 0.7 |
| 13 Other Manufacturing Products | "High Dis" | 0 | 4.1 |
| | "High Emb" | 18 | 0.3 |
| 14 Building & Construction | "High Dis" | 0 | 1.5 |
| | "High Emb" | 2 | 1.2 |
| 15 Trade | "High Dis" | 2 | 1.2 |
| | "High Emb" | 6 | 0.1 |
| 16 Lodging & Catering Services | "High Dis" | 0 | 1.2 |
| | "High Emb" | 4 | 0.7 |
| 17 Transport Services | "High Dis" | 0 | 1.3 |
| | "High Emb" | 4 | 0.3 |
| 18 Communication Services | "High Dis" | 0 | 5.4 |
| | "High Emb" | 10 | 3.8 |
| 19 Banking & Insurance | "High Dis" | 6 | 1.9 |
| | "High Emb" | 14 | 0.1 |

## 6. Simulation results

In this paragraph we report some preliminary and tentative results regarding the simulation properties of the Intimo model with the new productivity equations.

The main reason why we refer to these results as tentative is that the results are obtained by running the model in isolation (and not into the bilateral trade model), holding imports prices and exports exogenous.

Another reason has to do with wages equations. At the core of the determination of wages in Intimo there are wages in the industrial sector; sectoral wages are modelled (endogenously) as function of the industrial ones.

In a former version of the model industrial nominal wages' rate of growth was endogenous and modelled as a function of inflation and labor productivity.

Due to great changes in the Italian system of industrial relations during the 90's the old industrial wage equation is no longer able to predict wages' growth, and in the current version of the Intimo model an exogenous aggregate wage growth rate is assumed.

In spite of this, in the simulations reported in this paper we use the old equation to endogenously model the growth of industrial wages.

The reason is that, at least in this preliminary investigation about the properties of the model incorporating the new productivity equations, we think that is more interesting to evaluate the properties of a model in which labor productivity affects wages directly.

On the other hand, due to these caveats, in what follows we will focus on comparing and contrasting the results of the different models and not on the implications of the results for the Italian economy.

We compare the simulation results of three models: the old model and two models incorporating the new productivity equations. These two models differ regarding the assumption about the rates of embodied and disembodied technical progress: in a model we have assumed that, for each sector, the rates are those labeled as "High Dis" in table 5 and in the other one we have assumed that the rates are those labeled as "High Emb".

We refer to these three models as, respectively, the "Old Model", the "High Dis Model" and the "High Emb Model" (though actually the High Dis Model could be better labeled as "Only Dis").

We ran the three models under two different hypotheses about the growth of fixed investment:

i) "Low Inv"scenario: total fixed investments are assumed to grow at a constant rates of two percent;

ii) "High Inv" scenario: total fixed investments are assumed to grow at a constant rates of four percent.

Tables 6 to 8 show the results about some key macro variables for the three models.

Figures 1.a to 6.a report, for the three models, the predicted values of some key macro variables from the "Low Inv" scenario; figures 1.b to 6.b graph, for each model, the deviation of the "High Inv" simulation relative to the "Low Inv" simulation[8].

We think that the more interesting results are those about the comparison of the relative changes between the two scenarios.

The first important result that we can read in tables 6 to 8 it is that in all the three models the differences between the two simulations are of the same order of magnitude (and it is smaller in the new models): this is an important result since we were afraid that the new models could spiral out of control.

Another result that appears in the graphs it is the similarity in the response of the two models incorporating the new productivity equations and the great difference in the response of the new models with respect to the response of the old one.

[8] In all graphs the prefix "Old_" refers to the forecast of the Old Model (marked by +'s), the prefix "Dis_" refers to the forecast of the High Dis Model (marked by squares) and the prefix "Emb_" refers to the forecast of the High Emb Model (marked by x's).

In the Old Model the difference between the High Inv and the Low Inv simulation grows steadily and at an higher pace than in the other two models for all the variables reported here but personal consumption deflator, while in the High Dis and the High Emb model the differences stabilises or grows quite slowly (with the exception of personal consumption deflator) .

In all models the increase in investment increases employment but in the Old Model the difference between the “High Inv” and the “Low Inv” scenarios grows steadily over the whole forecast period (to almost 6% at the end of the forecast), while in the other two models the difference grows only at the beginning of the forecast, then it becomes almost constant in the High Dis Model and it decreases and then grows again in the High Emb Model.

The difference in the response of employment is not due to a corresponding difference in output (the difference in industrial output grows steadily in all the three models, though to a slightly higher rate in the Old one) but to a difference in the response of labor productivity. In the Old Model we have the counterintuitive result that productivity is higher in the “Low Inv” simulation than in the “High Inv” simulation, and the difference grows steadily. Instead in the other two models productivity is higher when investment is higher and the difference between the two simulations grows quite slowly and stabilises after the year 2005.

In the model an increase in labor productivity affects prices in two opposite ways: it decreases the unit labor cost but it increases nominal wages. In fact we find that the differences in real per capita wages are of the same sign than the differences in industrial labor productivity. On the other hand the difference in prices depends on which of the two effects prevails. In all the three models it is the nominal wages effect that prevails, but this result depends crucially on industrial nominal wages equation, an equation that needs to be re-estimated.

## Table 6

Titles of Alternate Runs
Line 1: Old Model (Low Inv Simulation)
Line 2: Old Model (High Inv Simulation)

Average rates of growth

Alternatives are shown as actual values.

MACRO RESULTS

| | 97-10 | 97-01 | 01-04 | 04-10 |
|---|---|---|---|---|
| Gross Domestic Product | 2.9 | 4.8 | 3.0 | 1.6 |
| | 3.2 | 5.2 | 3.3 | 1.9 |
| Personal Consump. Expenditure | 1.8 | 2.9 | 1.8 | 1.1 |
| | 2.1 | 3.2 | 2.0 | 1.4 |
| Fixed Investment | 2.0 | 2.0 | 2.0 | 2.0 |
| | 4.0 | 4.0 | 4.0 | 4.0 |
| Exports | 7.4 | 13.9 | 7.1 | 3.1 |
| | 7.4 | 13.9 | 7.1 | 3.1 |
| Imports | 5.7 | 8.7 | 5.8 | 3.7 |
| | 6.1 | 9.2 | 6.2 | 4.1 |
| Employment | 1.0 | 2.2 | 1.2 | 0.2 |
| | 1.4 | 2.6 | 1.6 | 0.6 |
| Aggregate Labor Prod. | 1.8 | 2.6 | 1.8 | 1.4 |
| | 1.8 | 2.6 | 1.7 | 1.3 |
| Industrial Labor Prod. | 3.6 | 4.9 | 3.5 | 2.7 |
| | 3.2 | 4.6 | 3.2 | 2.2 |
| GDP Deflator | 3.4 | 5.9 | 2.9 | 2.0 |
| | 3.4 | 5.9 | 2.9 | 2.0 |
| Personal Consump. Deflator | 2.9 | 4.8 | 2.6 | 1.7 |
| | 2.8 | 4.8 | 2.6 | 1.6 |
| Gross Output Deflator | 3.1 | 5.2 | 2.6 | 1.8 |
| | 3.0 | 5.2 | 2.6 | 1.8 |
| Exports Deflator | 3.0 | 5.4 | 2.6 | 1.5 |
| | 2.9 | 5.4 | 2.6 | 1.4 |
| Nominal Index of Ind. Wages | 3.7 | 6.0 | 3.4 | 2.4 |
| | 3.5 | 5.8 | 3.3 | 2.1 |
| Real Index of Ind. Wages | 0.8 | 1.2 | 0.8 | 0.7 |
| | 0.7 | 1.1 | 0.7 | 0.5 |
| Real Total Wages | 2.1 | 2.7 | 2.2 | 1.6 |
| | 2.4 | 3.0 | 2.5 | 1.9 |
| Real Per Capita Wages | 1.0 | 0.5 | 1.0 | 1.4 |
| | 0.9 | 0.4 | 0.9 | 1.3 |
| Real Households Income | 1.8 | 2.6 | 1.8 | 1.1 |
| | 2.0 | 2.9 | 2.0 | 1.4 |
| Real Total Profits | 3.4 | 6.8 | 3.2 | 1.4 |
| | 3.8 | 7.2 | 3.5 | 1.8 |

## Table 7

Titles of Alternate Runs
Line 1: High Dis Model(Low Inv Simulation)
Line 2: High Dis Model(High Inv Simulation)

Average rates of growth

Alternatives are shown as actual values.

MACRO RESULTS

| | 97-10 | 97-01 | 01-04 | 04-10 |
|---|---|---|---|---|
| Gross Domestic Product | 2.7 | 4.5 | 3.0 | 1.4 |
| | 3.0 | 4.8 | 3.2 | 1.7 |
| Personal Consump. Expenditure | 1.5 | 2.3 | 1.9 | 0.8 |
| | 1.6 | 2.5 | 1.9 | 0.9 |
| Fixed Investment | 2.0 | 2.0 | 2.0 | 2.0 |
| | 4.0 | 4.0 | 4.0 | 4.0 |
| Exports | 7.4 | 13.9 | 7.1 | 3.1 |
| | 7.4 | 13.9 | 7.1 | 3.1 |
| Imports | 5.7 | 8.6 | 5.9 | 3.6 |
| | 6.1 | 9.1 | 6.3 | 4.1 |
| Employment | 0.4 | 1.4 | 1.3 | -0.7 |
| | 0.4 | 1.5 | 1.2 | -0.7 |
| Aggregate Labor Prod. | 2.4 | 3.2 | 1.8 | 2.1 |
| | 2.6 | 3.3 | 2.0 | 2.3 |
| Industrial Labor Prod. | 4.7 | 6.3 | 3.8 | 4.1 |
| | 4.8 | 6.3 | 4.1 | 4.2 |
| GDP Deflator | 4.1 | 6.9 | 3.2 | 2.7 |
| | 4.2 | 7.0 | 3.3 | 2.8 |
| Personal Consump. Deflator | 3.4 | 5.6 | 2.8 | 2.2 |
| | 3.5 | 5.7 | 2.9 | 2.3 |
| Gross Output Deflator | 3.6 | 6.1 | 2.8 | 2.3 |
| | 3.7 | 6.2 | 3.0 | 2.4 |
| Exports Deflator | 3.5 | 6.2 | 2.9 | 2.0 |
| | 3.6 | 6.3 | 3.0 | 2.1 |
| Nominal Index of Ind. Wages | 4.7 | 7.6 | 3.7 | 3.2 |
| | 4.8 | 7.7 | 3.8 | 3.3 |
| Real Index of Ind. Wages | 1.3 | 2.0 | 0.8 | 1.1 |
| | 1.3 | 2.0 | 0.9 | 1.1 |
| Real Total Wages | 1.6 | 2.1 | 2.4 | 1.0 |
| | 1.7 | 2.3 | 2.3 | 1.1 |
| Real Per Capita Wages | 1.3 | 0.7 | 1.1 | 1.7 |
| | 1.3 | 0.7 | 1.1 | 1.7 |
| Real Households Income | 1.5 | 2.2 | 1.9 | 0.8 |
| | 1.6 | 2.4 | 1.9 | 0.9 |
| Real Total Profits | 3.5 | 6.6 | 3.2 | 1.5 |
| | 3.8 | 7.0 | 3.6 | 1.9 |

## Table 8

Titles of Alternate Runs
Line 1: High Emb Model (Low Inv Simulation)
Line 2: High Emb Model (High Inv Simulation)

Average rates of growth

Alternatives are shown as actual values.

MACRO RESULTS

| | 97-10 | 97-01 | 01-04 | 04-10 |
|---|---|---|---|---|
| Gross Domestic Product | 2.7 | 4.3 | 2.9 | 1.4 |
| | 2.9 | 4.6 | 3.1 | 1.7 |
| Personal Consump. Expenditure | 1.3 | 1.8 | 1.6 | 0.8 |
| | 1.4 | 2.0 | 1.6 | 1.0 |
| Fixed Investment | 2.0 | 2.0 | 2.0 | 2.0 |
| | 4.0 | 4.0 | 4.0 | 4.0 |
| Exports | 7.4 | 13.9 | 7.1 | 3.1 |
| | 7.4 | 13.9 | 7.1 | 3.1 |
| Imports | 5.6 | 8.4 | 5.9 | 3.6 |
| | 6.1 | 9.0 | 6.3 | 4.1 |
| Employment | -0.1 | 0.6 | 0.7 | -0.9 |
| | -0.0 | 0.7 | 0.5 | -0.8 |
| Aggregate Labor Prod. | 2.7 | 3.7 | 2.2 | 2.3 |
| | 3.0 | 3.9 | 2.6 | 2.5 |
| Industrial Labor Prod. | 5.7 | 7.8 | 5.1 | 4.5 |
| | 5.8 | 7.9 | 5.3 | 4.6 |
| GDP Deflator | 4.5 | 7.7 | 3.6 | 2.9 |
| | 4.7 | 7.9 | 3.8 | 3.1 |
| Personal Consump. Deflator | 3.7 | 6.2 | 3.1 | 2.3 |
| | 3.8 | 6.3 | 3.3 | 2.4 |
| Gross Output Deflator | 4.0 | 6.8 | 3.2 | 2.5 |
| | 4.1 | 6.9 | 3.4 | 2.6 |
| Exports Deflator | 3.9 | 6.8 | 3.2 | 2.2 |
| | 4.0 | 7.0 | 3.4 | 2.3 |
| Nominal Index of Ind. Wages | 5.4 | 8.9 | 4.4 | 3.5 |
| | 5.5 | 9.1 | 4.6 | 3.6 |
| Real Index of Ind. Wages | 1.7 | 2.7 | 1.2 | 1.2 |
| | 1.7 | 2.7 | 1.3 | 1.2 |
| Real Total Wages | 1.4 | 1.6 | 2.0 | 1.0 |
| | 1.5 | 1.7 | 1.9 | 1.1 |
| Real Per Capita Wages | 1.5 | 1.0 | 1.3 | 1.9 |
| | 1.5 | 1.1 | 1.3 | 1.9 |
| Real Households Income | 1.4 | 1.9 | 1.6 | 0.8 |
| | 1.5 | 2.0 | 1.6 | 1.0 |
| Real Total Profits | 3.5 | 6.6 | 3.3 | 1.6 |
| | 3.9 | 7.0 | 3.6 | 2.0 |

**Fig. 1.a**

EMPLOYMENT

LowInv Simulations

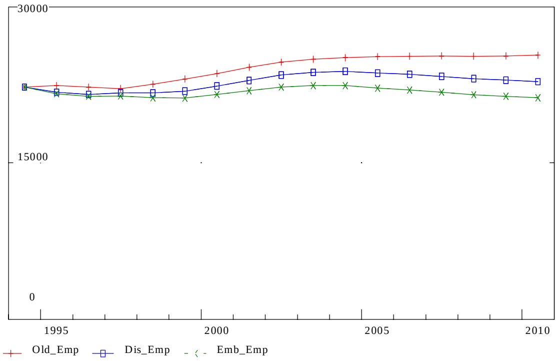



**Fig. 1.b**

EMPLOYMENT

perc. diff. between HighInv and LowInv

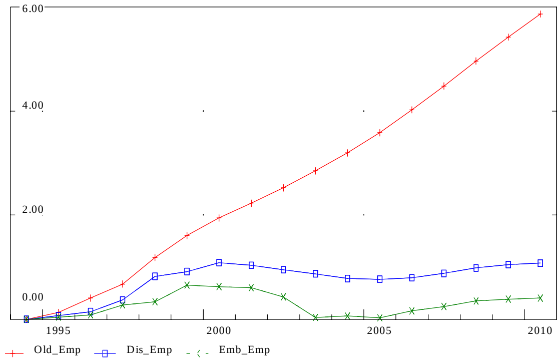



**Fig. 2.a**

INDUSTRIAL LABOR PRODUCTIVITY

LowInv Simulations

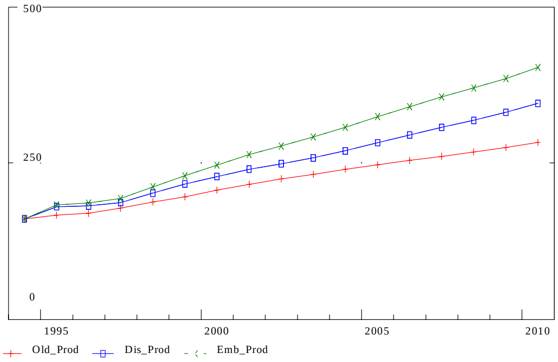



**Fig. 2.b**

INDUSTRIAL LABOR PRODUCTIVITY

perc. diff. between HighInv and LowInv

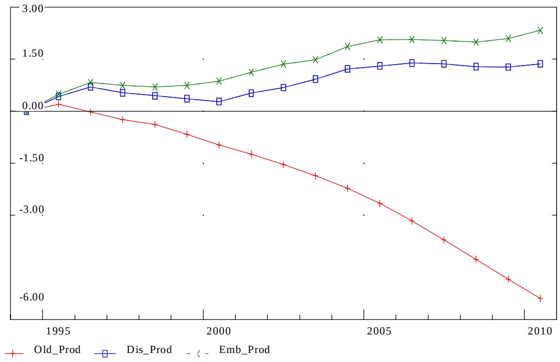



**Fig. 3.a**

PERSONAL CONSUMPTION

LowInv Simulations

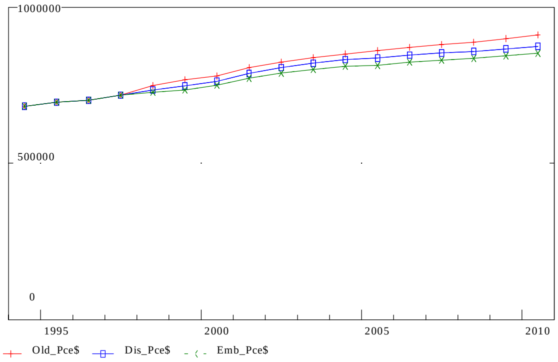



**Fig. 3.b**

PERSONAL CONSUMPTION

perc. diff. between HighInv and LowInv

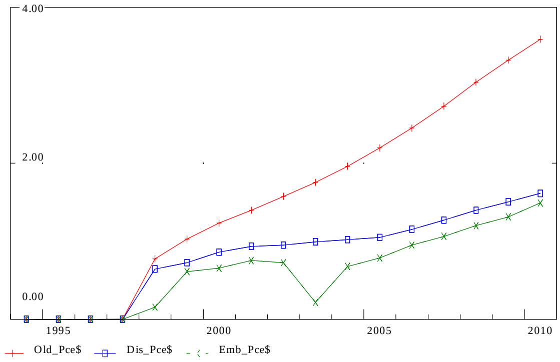


**Fig. 4.a**

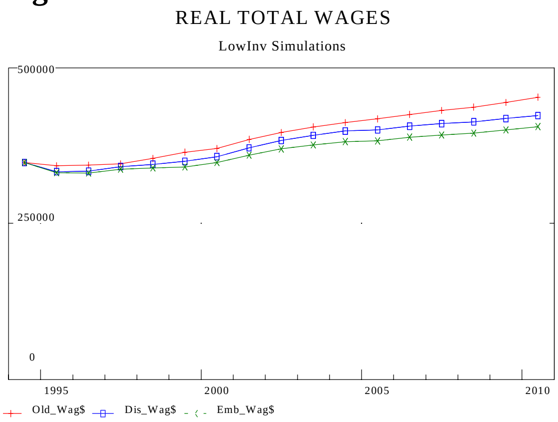



**Fig. 4.b**

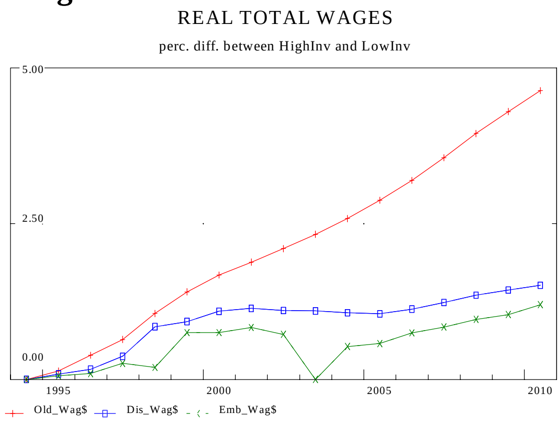



**Fig. 5.a**

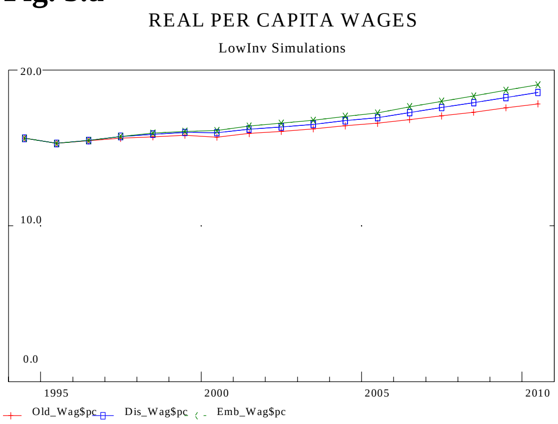



**Fig. 5.b**

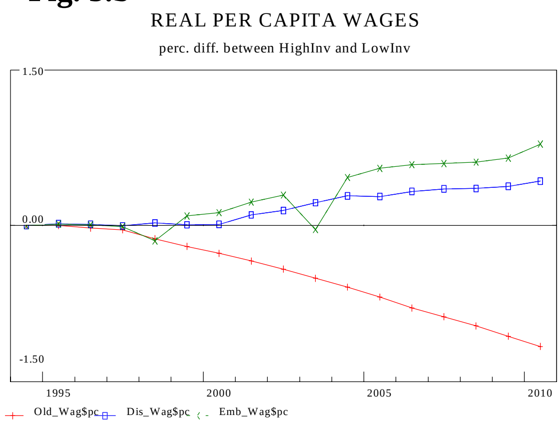



**Fig. 6.a**

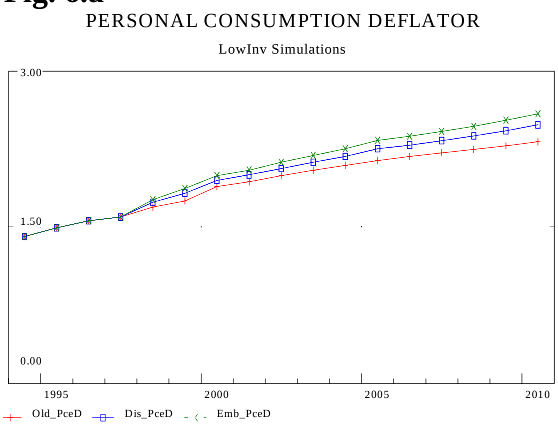
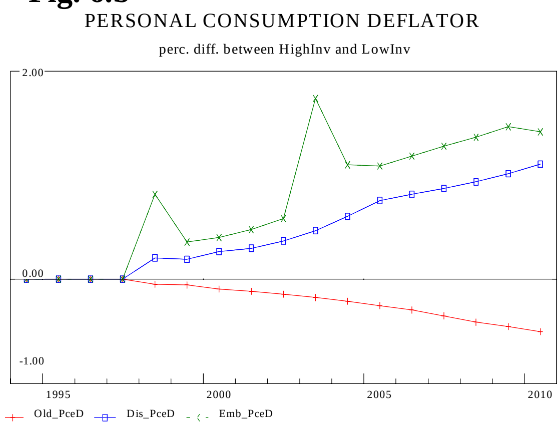



**Fig. 6.b**



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Appendix A: data description

All data used for this paper are from the Italian national accounts published by ISTAT.

The data used for paragraph 3 are from the new national accounts that ISTAT started to publish in 1999.

The innovations in the new series are important: besides the new concepts and definitions from ESA95, also new calculation methods (both for current prices variables and deflation methods), new statistical sources, and a new classification system (the so called Nace Rev.1.) have been applied (Pisani, 2000).

Gross output at constant prices and value added at current prices are evaluated at basic prices.

Employment is measured in terms of full-time equivalent employees, which is a definition taking into account cases such as part-time employment, job duplication and so on.

Investments in constant prices are obtained by deflating investments in current prices by the non-durable consumption expenditure deflator.

The capital stock is obtained by a simple application of the perpetual inventory method directly to the series of total investment. We assumed a geometric depreciation rate equal to 5 percent in all sectors (that is supposed to accounts only for physical deterioration). We didn't adjust for discards. The series of investment by purchaser (like all the other ones) are available from the year 1970 onwards, while our regressions' limits start from 1983. Since a longer series would be desirable to construct the capital stock, we have used the *unit buckets* correction proposed by Almon (1990) in order to correct for the use of not that long series.

## Appendix B: factor shares calculation.

Assuming constant returns to scale we can calculate the capital share in values added simply as (1- labor share).

Computing the labor share is certainly easier than computing directly the capital share, but it is not straightforward.

The problem is that there is not a one-to-one relation between the theoretical variable "income that goes to labor" and the variable that we can find in the national accounts.

In fact the remuneration of labor is not directly observable (at least if our eyes are the European national accounts): what is directly observable is the remuneration of employees ("redditi da lavoro dipendente" in the Italian national accounts), while the remuneration of self-employed is a component of the gross operating surplus ("risultato lordo di gestione").

One way to solve this problem is to assume that employees and self-employed in the same sector earn the same per capita income.

With this assumption we can calculate the per-capita income of employees and then get an imputation for the remuneration of labor by multiplying this per-capita income by the total number given by employees plus self-employed.

The previous assumption is clearly unrealistic and it will be misleading if we want to use it to estimate total income that goes to self-employed, but maybe it is more acceptable if we want to use it to estimate the share of this income that is a remuneration for their direct contribution as workers.

This assumption has been used, e.g., in ISTAT (1995).