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Yeasty vs. mushroom-like patterns of hyper-integrated productivity growth: An analysis of six advanced industrial economies*

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Abstract The aim of this paper is to apply a visualisation technique for depicting sectoral concentration patterns of technical change to a disaggregated physical productivity measure, which is based on the notion of hyper-integrated labour content of commodities. An empirical application to a set of six advanced industrial economies (US, UK, Germany, Japan, France and Italy) during the 1995-2005 period allows to conclude that a high productivity growth regime seems to be more compatible with a less uneven/localised pattern of technological development.

Keywords Input-Output Analysis · Vertically hyper-integrated labour · Harberger diagram

1 Introduction

In Harberger (1998), a particular Lorenz-curve type of diagram is introduced, which displays the cumulated absolute contribution of each industry to aggregate TFP growth, according to its cumulated share

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in initial value added. From the form of the curve, it is possible to infer relative sectoral contributions to aggregate performance. In particular, Harberger (1998, p. 4) coined the distinction between a 'yeasty' and 'mushroom' pattern, representing a balanced and broad growth pattern as opposed to an uneven and localised one, and conjectured that a 'mushroom' vision dominates the growth process.

However, given that TFP growth reflects *additive* real *cost* reductions rather than physical productivity changes, Harberger's diagrams could be applied to Pasinetti's (1988) physical notion of vertically hyper-integrated labour content of commodities, to identify the concentration pattern of total labour-saving trends among a set of growing sub-systems (in the sense of Sraffa, 1960, p. 89).

Hence, by switching the disaggregated unit of analysis from industries to (growing) sub-systems, Harberger diagrams are devised from a set of Input-Output accounts, fixed-capital flow matrices and labour input coefficients; depicting hyper-integrated productivity patterns and, thus, evaluating Harberger's conjectures with respect to this productivity measure for six advanced industrial economies (US, UK, Germany, Japan, France and Italy) during the 1995-2005 period.

2 Analysis: Harberger diagrams and hyper-integrated productivity growth

The highly abstract notion of TFP was brought down to earth by Harberger (1998), by emphasizing that TFP Growth (TFPG, hereinafter) represents merely a reduction in real costs:

> I think it would be perfectly fair to characterize my presentation today as a paean in praise of "real cost reduction" as a standard label for R' [TFPG]. Labels do not change the underlying reality, but they may change the way we look at it and the way we think about it.
>
> (Harberger, 1998, p. 3)

Consequently, Harberger (1998, p. 4) realised that these reductions in real costs were *additive* if turned into monetary units by computing TFPG as a percentage of initial value added at base year prices. But adding absolute real cost reductions gave rise to the possibility of studying their *degree of concentration*.

To that end, he proposed (Harberger, 1998, pp. 4-10) a particular Lorenz-curve type of diagram (a Harberger diagram, hereinafter), that displays the cumulated absolute contribution to TFPG of each industry (on the y-axis), according to its cumulated share in initial value added (on the x-axis). By rescaling the y-axis in such a way that the y-value corresponding to the x-value of 100% equals the aggregate TFPG rate, and ordering industries (in a decreasing order) according to their growth *rate*, a concave diagram like Figure 1 obtains, displaying the industry pattern of absolute contributions to overall real cost reduction.

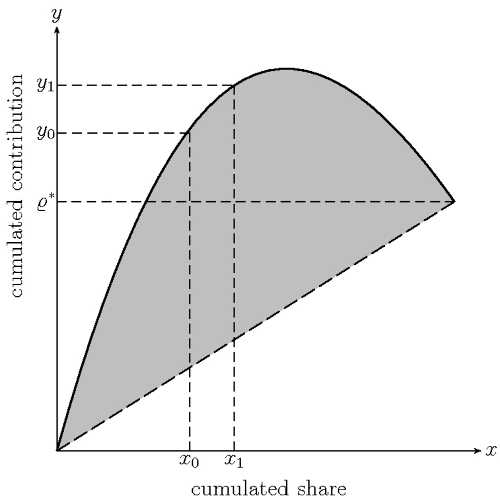

Fig. 1 Harberger diagram

From the form of the curve it is possible to infer the pattern of growth of the different components that contribute to the aggregate. In particular, Harberger (1998, p. 4) introduced the distinction between a 'yeasty' and 'mushroom' pattern, representing a balanced and broad growth pattern as opposed to an uneven and localised one.[1]

Harberger's 'mushrooms' vision of the growth process is characterised by the following features:

> (i) a small-to-modest fraction of industries can account for 100 percent of aggregate real cost reduction in a period; (ii) the complementary fraction of industries contains winners and losers, the TFP contributions of which cancel each other; (iii) the losers are a very important part of the picture most of the time, and contribute greatly to the variations we observe in aggregate TFP performance; and (iv) there is little evidence of persistence from period to period of the leaders in TFP performance.
>
> (Harberger, 1998, p. 10)

In a series of recent studies, this visualisation device has been used to analyse the pattern of growth of value-added per worker, investment in ICT products and TFPG of a broad sample of advanced industrial economies (see, e.g. Peneder, 2005; Inklaar and Timmer, 2007; Timmer et al, 2010).

In contradistinction, we intend to depict Harberger diagrams for vertically hyper-integrated labour productivity changes,[2] and evaluate Harberger's conjectures but with respect to our productivity measure. In fact, this notion lends itself more naturally to a conceptualisation in absolute terms, as hyper-integrated labour productivity growth amounts to a saving of labour, and units of employment *are* additive. Hence, the 'real cost reduction' in our case is a 'saving of units of labour'.

[1] In Harberger's (1998, p. 4) words: "The analogy with yeast and mushrooms comes from the fact that yeast causes bread to expand very evenly, like a balloon being filled with air, while mushrooms have the habit of popping up, almost overnight, in a fashion that is not easy to predict".

[2] See Garbellini and Wirkierman (2014) for a detailed methodological presentation of the concept and measurement of hyper-integrated labour productivity changes.

To derive the above-mentioned measure of productivity changes, depart from the dual system of expenditure-income relations of an Input-Output accounting framework:[3]

$$\mathbf{x} = \mathbf{X}_d\mathbf{e} + \mathbf{k}_d + \mathbf{c}_d \tag{1}$$

$$\mathbf{x}^T = \mathbf{e}^T\mathbf{X}_d + \mathbf{e}^T\mathbf{X}_m + \boldsymbol{\tau}_q^T + \mathbf{y}^T \tag{2}$$

where $\mathbf{x}$ stands for gross output by industry, $\mathbf{X}_d$ is the matrix of circulating capital inputs, $\mathbf{k}_d$ is the vector of gross capital formation by industry of origin, $\mathbf{c}_d$ is the vector of final consumption demand,[4] $\mathbf{X}_m$ is the matrix of imported circulating capital inputs, $\boldsymbol{\tau}_q^T$ is the vector of net taxes on products and $\mathbf{y}^T$ is the vector of gross value added by industry.

Expression (1) represents the nominal counterpart to the product balances of the economy, depicting a process of commodity circulation, while expression (2) captures the cost-revenue relations of each industry. From the former, it is possible to recover the system of physical quantities, whereas from the latter, the system of relative prices. In fact, disaggregated system measures of physical productivity changes depart from expression (1), while profitability or 'real cost reduction' measures, like TFP growth, from expression (2).

[3] We are considering a single-product square industry × industry setting, obtained from a set of Supply-Use Tables (SUT) by applying the fixed product sales structure transformation model. For a detailed presentation of the main procedures for transforming Supply and Use Tables into square Input-Output tables see EUROSTAT (2008, ch. 11). As regards notation, matrices are represented using boldface upper-case letters (e.g. $\mathbf{M}$), vectors with boldface lower-case letters (e.g. $\mathbf{v}$), all vectors are column vectors, and their transposition is explicitly indicated (e.g. $\mathbf{v}^T$). A vector with a hat (e.g. $\widehat{\mathbf{v}}$) indicates a diagonal matrix with each element of the vector on the main diagonal. Vector $\mathbf{e} = [1, \ldots, 1]^T$ is an $n \times 1$ column vector that sums across columns, while $\mathbf{e}_j = [0, \ldots 0, 1, 0 \ldots, 0]^T$ is an $n \times 1$ column vector that selects the $j - th$ column. The same applies for vector $\mathbf{e}_j^T$ with respect to rows. All vectors are of dimension $n \times 1$, and all matrices are of dimension $n \times n$.

[4] The subscript d in the right-hand side magnitudes of equation (1) stands for domestically produced (as opposed to imported commodities).

In this paper, therefore, the focus will be on the expenditure side for domestic output (1). Note, in this regard, that the crucial distinction between capital formation ($\mathbf{k}_d$) and final consumption demand ($\mathbf{c}_d$) is given by the capacity generating effects of the former with respect to the latter, i.e. to the fact that demand for new capital goods re-enter the circular flow while private and public consumption together with exports constitute the physical surplus of the system.[5]

In this sense, it is assumed that *gross* investments (i.e. demand for replacements and new investments) are part of the means of production, and their level induced by the growth rate of effective demand for final uses. In this case, vector $\mathbf{k}_d$ will not suffice to describe expenditure on fixed capital goods by each industry, so we actually have:

$$\mathbf{k}_d = \mathbf{K}_d \mathbf{e} \tag{3}$$

where $\mathbf{K}_d$ is a matrix of gross fixed capital flows (and changes in inventories) domestically produced by industry of origin (row-wise) and destination (column-wise). By introducing (3) in (1), the expenditure system for domestic output can be written as:

$$\mathbf{x} = \mathbf{X}_d \mathbf{e} + \mathbf{K}_d \mathbf{e} + \mathbf{c}_d \tag{4}$$

A crucial point in (4) is that the notion of *net output* is modified with respect to the traditional concept of final demand. In this context, both aggregate and sectoral productivity measures shall be defined taking the final consumption vector $\mathbf{c}$ as the physical surplus, i.e. net output, of the system (Pasinetti, 1986). Note, moreover, that system (4) considers only domestically produced commodities,[6] and magnitudes are given at basic prices[7], i.e. taxes on products are separated from intermediate transactions, and trade

[5] As has been emphasized by Pasinetti (1981, p. 176): "It is this *derived demand* aspect of investment goods, due to their being used as means of production, that is new and typical of production systems".

[6] A separate set of product balances for imports could be constructed as well.

[7] See EUROSTAT (2008, p. 163) for a definition and discussion.

and transport margins have been re-allocated to the corresponding specific cells of intermediate input matrices.

Consider re-partitioning system (4) into n different parts, each producing a composite commodity for final uses, according to the product mix of industry j.[8] To each of these parts we shall call growing (or hyper-) subsystems (Pasinetti, 1981, 1988). In formal terms, vector $\mathbf{c}_d$ may be partitioned as:

$$\mathbf{c}_d = \sum_j^n \mathbf{c}_d^{(j)} = \sum_j^n \widehat{\mathbf{c}}_d \mathbf{e}_j = \sum_j^n \mathbf{e}_j c_j \tag{5}$$

where $\mathbf{c}_d = [c_j]$.

The vector of gross industry outputs associated to hyper-subsystem j is given by:

$$\mathbf{x}^{(j)} = (\mathbf{I} - \boldsymbol{\Lambda})^{-1}\mathbf{c}_d^{(j)}, \quad j = 1, \ldots, n \tag{6}$$

with:

$$\boldsymbol{\Lambda} = (\mathbf{X}_d + \mathbf{K}_d)\widehat{\mathbf{x}}^{-1} \tag{7}$$

Turning now to labour inputs, consider the industry employment vector $\mathbf{l} = [L_j]$, with $L = \mathbf{l}^T\mathbf{e}$. By defining the row vector of employment requirements per unit of industry output as: $\mathbf{a}_l^T = \mathbf{l}^T\widehat{\mathbf{x}}^{-1}$, a measure of comprehensive labour inputs associated to subsystem j is:

$$L_\eta^{(j)} = \mathbf{a}_l^T\mathbf{x}^{(j)} = \boldsymbol{\eta}^T\mathbf{c}_d^{(j)} = \boldsymbol{\eta}^T\mathbf{e}_j c_j = \eta_j c_j \tag{8}$$

$$\boldsymbol{\eta}^T = \mathbf{a}_l^T(\mathbf{I} - \boldsymbol{\Lambda})^{-1} \tag{9}$$

where $\boldsymbol{\eta}^T$ is the vector of vertically hyper-integrated labour coefficients, and scalar $L_\eta^{(j)}$ summarises total labour requirements to replace and expand/contract final uses of industry j. It is the product

[8] Traditionally, subsystems have been defined with respect to a single commodity, even in square joint-product systems of commodity × activity type. However, given that our dataset will be based on the application of the fixed product sales structure assumption (Yamano and Ahmad, 2006, section 7), each industry produces a composite commodity identifying every subsystem.

of two components: labour intensity per unit of final consumption, η_j, times (monetary) units of final consumption, c_j.

Note that η_j is computed for every subsystem j, but it depends on the technique in use of *all* industries. This is because it captures the redistribution of total employment that takes place when the unit of analysis is shifted from the industry to the *growing* subsystem. Differently from the traditional notion of vertically *integrated* labour coefficient (Pasinetti, 1973), η_j includes the labour requirements to *expand* (and not only to self-replace) productive capacity.

Hence, *hyper-integrated* labour productivity for growing subsystem j can be computed as:

$$\alpha_\eta^{(j)} = \frac{c_j}{L_\eta^{(j)}} = \frac{1}{\eta_j} = \frac{1}{\mathbf{a}_l^T(\mathbf{I} - \boldsymbol{\Lambda})^{-1}\mathbf{e}_j}, \quad j = 1 \dots n \tag{10}$$

whereas proportional changes may be computed as: $\Delta\%\alpha_\eta^{(j)} \approx d\ln(\alpha_\eta^{(j)})$.

Note that $\alpha_\eta^{(j)}$ does not directly depend on the structure of final consumption. Instead, any aggregate measure of labour productivity changes will depend on the composition of net output (Pasinetti, 1981, pp. 97-99). In particular, when working in hyper-integrated terms, the synthetic indicator relating subsystem productivity growth with the composition of final consumption demand is given by the standard rate of productivity growth, ρ^*, introduced by Pasinetti (1981, pp. 101-104). In this context it may be computed as:

$$\rho^* = \frac{\sum_j d\ln(\alpha_\eta^{(j)})L_\eta^{(j)}}{\sum_j L_\eta^{(j)}} \tag{11}$$

Expression (11) shows that ρ^* is a weighted average of the rates of change of vertically hyper-integrated labour productivity $d\ln(\alpha_\eta^{(j)})$, the weights being the quantities of total labour of the corresponding *subsystem* j, $L_\eta^{(j)}$. By inspecting (8) it can be immediately seen that $L_\eta^{(j)}$ depends on c_j.

3 Empirical exploration: Patterns of labour-saving trends

After having derived a measure for hyper-subsystem labour productivity growth and aggregate productivity changes, this section applies the visualization technique of Harberger (1998) diagrams to study the pattern of productivity changes of six OECD economies during the period 1995-2005.[9] The dataset used for the computations comes from two OECD databases: OECD Input-Output Database 2010 Edition and STructural ANalysis (STAN) Database.[10]

If $L_\eta^{(j)}$ represents hyper-subsystem labour — as defined in (8) — and $\alpha_\eta^{(j)}$ is the level of hyper-integrated labour productivity — as defined in (10), then the absolute labour saving within each hyper-subsystem j is given by:

$$LS_\eta^{(j)} = L_\eta^{(j)} \left(1 - e^{-d \ln \alpha_\eta^{(j)}}\right), \qquad j = 1, \ldots, n \tag{12}$$

Table 1 reports the absolute saving of labour within every hyper-subsystem for each sub-period and country. Numbers represent thousand of employment units (th. EMP).

Positive figures in Table 1 indicate a *reduction* in hyper-subsystem labour, everything else being equal. Given that, in general, total employment has increased, overall labour saving trends have been offset by increases in final effective demand by commodity. This is precisely the interplay between productivity growth and changes in final consumption demand at the basis of Pasinetti's (1981, pp. 94-97) structural dynamics of employment.

From the absolute labour saving of each hyper-subsystem ($LS_\eta^{(j)}$) and its share on total employment ($L_\eta^{(j)}/L$), it is possible to construct Harberger diagrams. To do this, we compute the cumulated

[9] Hereinafter, country codes refer to: DE: Germany, FR: France, IT: Italy, JP: Japan, UK: United Kingdom, and US: United States.

[10] The databases can be obtained from: `www.oecd.org/sti/inputoutput` and `oe.cd/stan`, respectively. Particular characteristics of the dataset, as well as data preparation procedures are detailed in Wirkierman (2012, Appendix F).

Table 1 Absolute labour saving in the growing subsystem - $LS_{\eta}^{(j)}$ (in average yearly thousand employment units)

	DE		FR		IT		JP		UK		US	
Sector	95-00	00-05	95-00	00-05	95-00	00-05	95-00	00-05	95-00	00-05	95-00	00-05
ABC:Primary	15.43	14.09	19.65	3.73	17.40	1.76	60.96	40.97	33.57	1.79	31.66	−8.45
DA:Food-Tobacco	56.20	36.76	13.25	12.30	54.26	9.80	204.19	8.31	15.62	46.37	−20.55	71.89
DB-C:Textiles-Leather	28.19	12.66	24.00	10.97	49.63	4.55	7.57	15.01	5.67	34.35	90.31	64.92
DD:Wood	2.22	2.18	1.59	1.22	2.75	1.03	0.23	0.54	−0.35	0.76	39.47	3.10
DE:Paper-Printing	26.01	18.13	7.28	3.91	5.50	3.48	2.68	16.49	−3.82	18.59	20.34	75.72
DF:Coke-Petroleum	24.58	−0.75	3.02	−1.64	0.80	−2.63	0.42	5.90	9.41	8.61	−8.07	−19.95
DG:Chemicals	61.65	24.78	23.02	9.32	17.64	8.73	3.52	14.17	21.74	42.21	−0.30	40.94
DH:Plastics	5.48	12.82	5.81	4.19	4.28	2.77	0.01	9.74	−1.11	8.96	5.39	14.07
DI:Non-met. minerals	5.19	3.57	1.92	1.04	4.13	−0.31	2.67	6.54	3.08	6.32	1.36	4.95
DJ:Metals	32.56	34.49	8.73	3.10	8.97	4.12	10.29	−7.90	11.30	23.33	23.14	11.74
DK:Machinery n.e.c.	49.18	42.06	13.96	11.07	15.86	6.87	33.11	29.51	8.23	33.34	22.68	32.15
DL:Electr. Machinery	52.03	31.49	17.60	30.55	15.38	2.95	184.51	291.32	72.41	26.99	242.41	254.65
DM:Transport Equip.	54.15	101.81	53.86	20.66	22.32	−4.51	74.29	67.58	23.13	48.57	74.01	102.45
DN:Manufacture n.e.c.	16.29	11.61	7.92	4.81	8.12	−1.02	1.65	17.36	−4.95	17.94	−36.83	57.96
E:Energy	39.93	17.96	6.38	10.27	4.40	−0.74	29.64	61.94	27.83	23.53	147.58	−21.54
F:Construction	3.59	1.85	0.77	−0.33	0.53	−1.23	0.00	0.01	1.28	−1.10	2.30	−0.01
G:Trade	78.09	117.62	−9.13	8.22	1.98	−10.11	59.77	228.44	44.85	169.00	783.13	635.76
H:Hotel-Restaurant	−0.08	−37.15	10.71	−4.42	24.07	−35.33	30.29	56.41	−40.92	30.80	138.78	105.26
I:Transport-Comm.	99.14	37.92	45.04	27.93	15.71	19.52	60.59	156.46	70.45	63.36	46.07	289.26
J:Finance	18.88	21.31	8.85	5.48	7.89	1.72	8.59	63.48	71.57	30.10	285.83	399.07
K:Business Services	26.09	97.90	1.51	3.77	−16.79	−33.34	−167.97	618.61	33.06	64.59	−181.80	210.32
L:Public Admin.	71.70	62.32	36.43	24.02	10.66	26.74	99.63	383.31	30.86	−16.43	−878.46	468.42
M:Education	19.49	−18.88	8.98	8.48	−6.41	7.97	3.35	59.11	−39.22	−30.28	287.58	23.98
N:Health	90.69	51.73	15.77	22.60	−2.67	4.50	94.02	64.07	85.35	66.88	264.61	332.93
OP:Personal Services	21.15	−14.24	14.46	13.09	6.58	−42.24	−23.66	−29.35	−24.51	5.71	−205.32	56.26

Source: Own Computations based on OECD Input-Output and STAN Databases contribution to overall labour saving for every hyper-subsystem (y-axis) and the associated cumulated hyper-subsystem labour share in total employment (x-axis):

$$(y\text{-axis}) \qquad y_j = \sum_{k \in \Omega_j} LS^{(k)}$$

$$(x\text{-axis}) \qquad x_j = \sum_{k \in \Omega_j} L_\eta^{(k)}/L$$

$$j = 1, \ldots, n; \quad \Omega_j = \{k : d \ln \alpha_\eta^{(k)} \geq d \ln \alpha_\eta^{(j)}\}$$

rescaling the y-axis in such a way that $y_n = \rho^*$, for $n : x_n = 1$, where ρ^* is the standard rate of growth of productivity, defined in (11).

Figures 2 to 7 display the Harberger diagrams for each country. The dotted line in each Figure represents the level of ρ^*, while the letters inside each diagram report the activity codes identifying the position of selected hyper-subsystems.

In order to compare diagrams across countries and periods, it is helpful to devise some summary statistics to grasp pattern differences more easily. This has been done by Inklaar and Timmer (2007, pp. 177-8), who proposed to compute (besides aggregate productivity growth, ρ^* in our case):

> [I] The cumulative share of industries with positive contributions, as an indicator of the *pervasiveness* of growth.
>
> [II] The *curvature* as measured by the area between the diagram and the diagonal line [...] divided by the total area beneath the diagram. This relative area measure lies between zero and one. It is zero when all industries have equal growth and, when industry growth rates start to diverge, the relative area increases.
>
> (Inklaar and Timmer, 2007, pp. 177-8, our italics)

Instead of working with industries, we shift to the hyper-subsystem as unit of analysis. As to the indicators, high pervasiveness (which ranges from 0 to 100%) would argue in favour of a more 'yeasty' pattern of growth, while the curvature intends to capture the localised (diverging) or diffused (converging) path of absolute labour saving by subsystem that leads to the final aggregate outcome. Note that a zero curvature indicates that all subsystems have increased their productivity at the aggregate rate ρ^*.

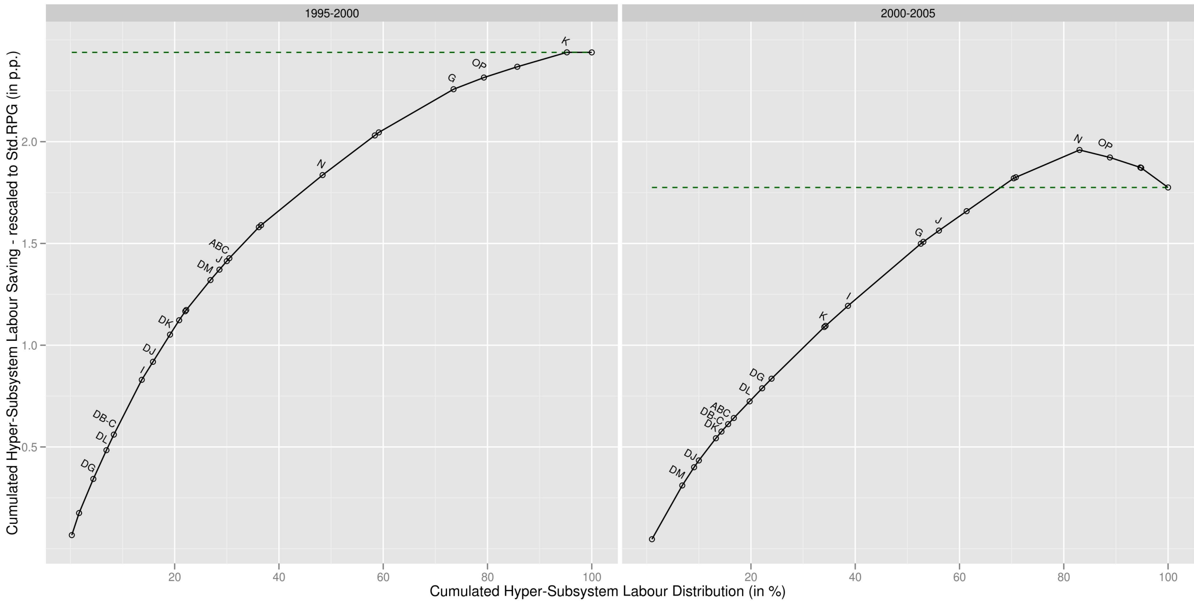

Fig. 2 Harberger diagrams for Germany (1995-2005)

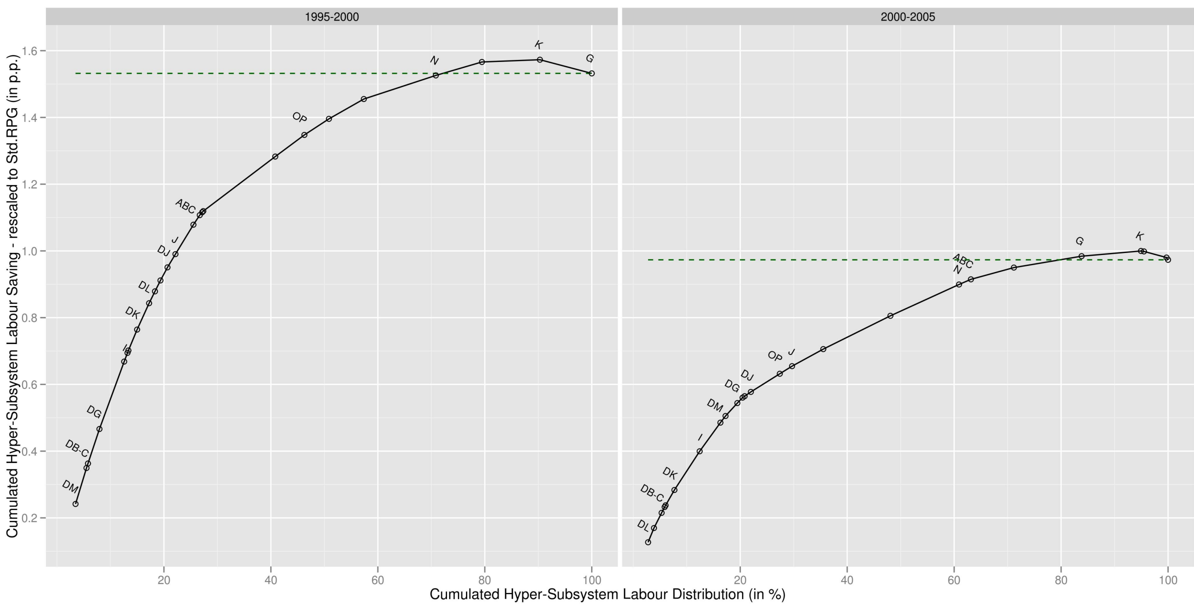

Fig. 3 Harberger diagrams for France (1995-2005)

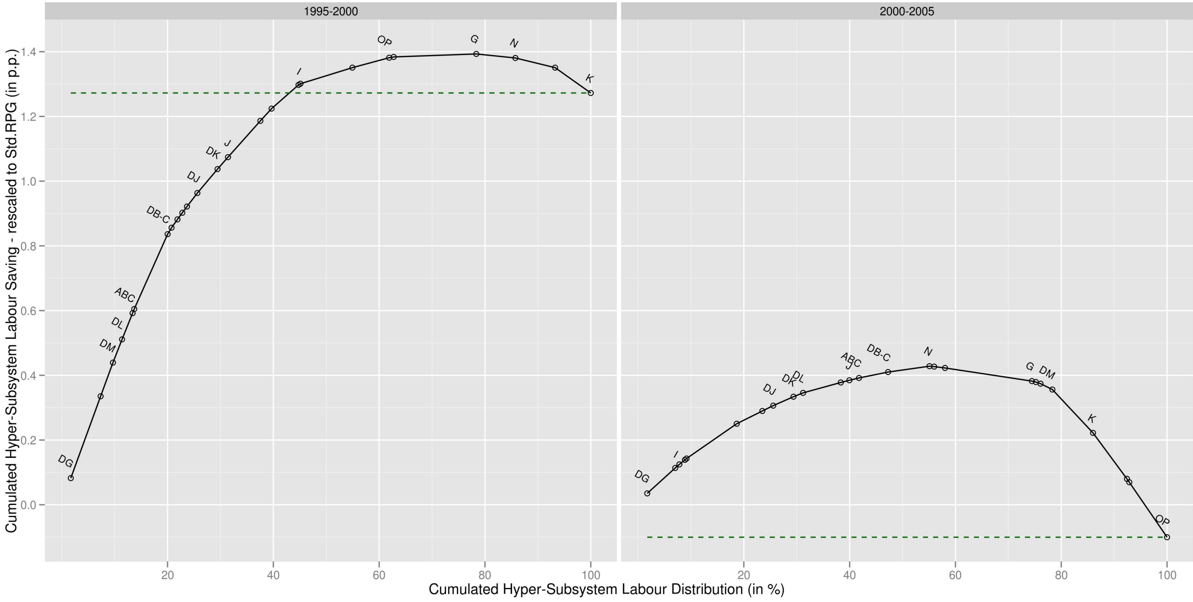

Fig. 4 Harberger diagrams for Italy (1995-2005)

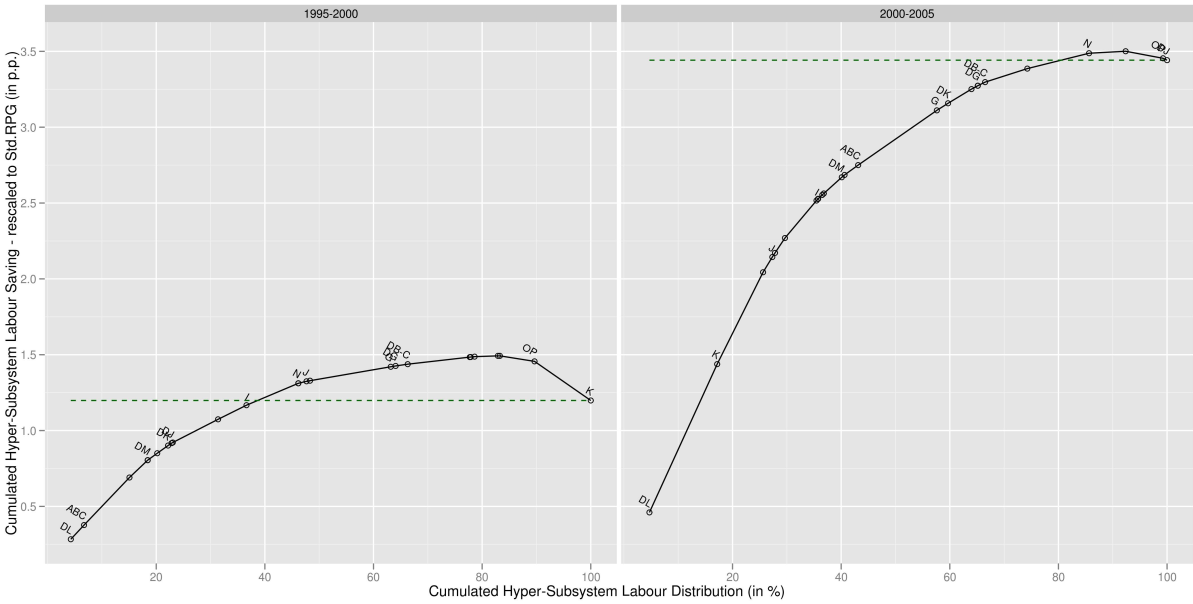

Fig. 5 Harberger diagrams for Japan (1995-2005)

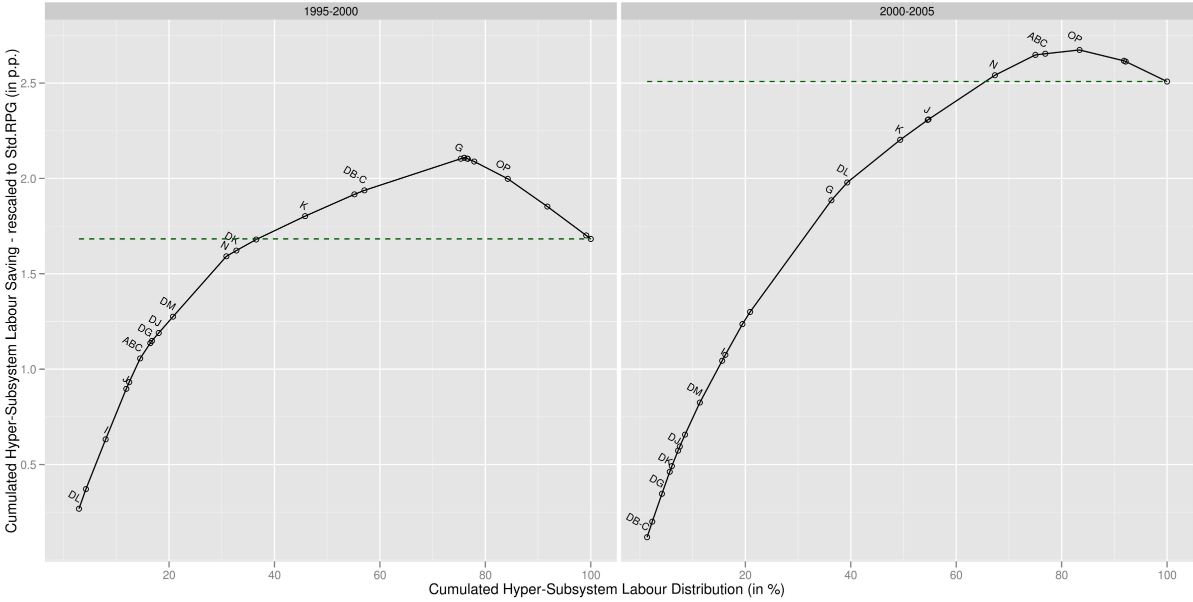

Fig. 6 Harberger diagrams for the UK (1995-2005)

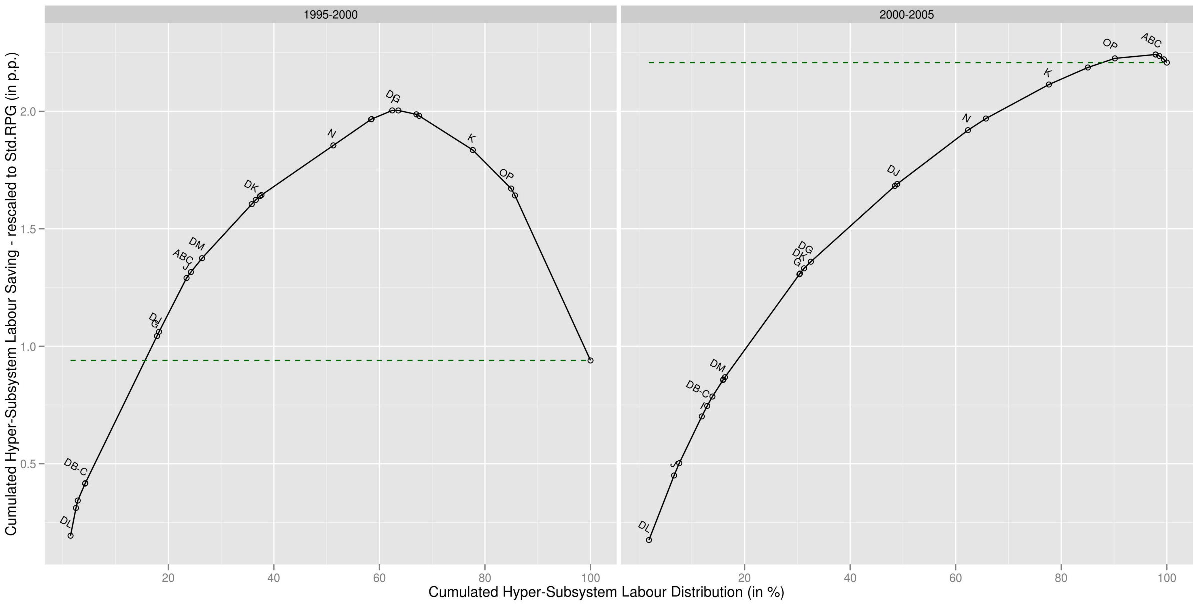

Fig. 7 Harberger diagrams for the US (1995-2005)

Intuitively, the pervasiveness indicator identifies the value of the x-axis for which the contribution of the sector to aggregate productivity growth is no longer positive, while the curvature indicator measures the extent to which sectoral growth differs from the evolution of aggregate productivity.

Table 2 reports the summary statistics associated to Harberger diagrams for the six economies studied.

Table 2 Yeast vs. Mushrooms Patterns for Vertically hyper-integrated Labour Productivity Growth (1995-2005)

Country	ρ^*		**Pervasiveness**		**Curvature**	
	95-00	00-05	95-00	00-05	95-00	00-05
DE	2.44	1.78	95.23	83.01	0.28	0.32
FR	1.53	0.97	90.30	94.94	0.38	0.35
IT	1.27	-0.10	78.36	55.09	0.43	0.87
JP	1.20	3.44	83.27	92.37	0.47	0.33
UK	1.68	2.51	76.00	83.40	0.48	0.36
US	0.94	2.21	62.43	97.87	0.68	0.29

Source: Own Computation based on OECD Input-Output and STAN Databases.

Notes: ρ^* is measured in average yearly percentage points, Pervasiveness is measured in %, Curvature ranges from 0 (balanced/uniform pattern) to 1 (uneven/localised pattern).

To begin with, the three countries with an acceleration of productivity growth (Japan, UK and the US) have experienced an increasing pervasiveness and declining curvature in their pattern of growth, suggesting a transition towards a 'yeasty' behaviour. Both Japan and the US have made a transition from a low-medium (1995-2000) to a high (2000-2005) value of ρ^*. The reduction in the curvature of Japan and the UK has been considerable, but that of the US has been truly noticeable (from 0.68 to 0.29, i.e. the highest of the 1995-2000 period and the lowest of the 2000-2005 period across countries).

Instead, for those economies de-accelerating their productivity growth (Germany, France and Italy), no uniform behaviour can be established. Germany, keeping however high productivity growth rates in both periods, has reduced its pervasiveness and increased its curvature, suggesting a 'mushroom' pattern of growth, while in France exactly the opposite has occurred, though to a really milder extent.

The case of Italy is of interest. Productivity growth collapsed (it even turned negative for the 2000-2005 period), pervasiveness has decreased sharply and its curvature has increased to such extent that it has had the greatest change (in absolute value) across countries (from 0.43 to 0.87). In Italy, subsystems that add up to a little more than half of total employment amount to the only positive contributions to productivity changes, while the other (almost) half has had negative productivity growth. This suggests a clear 'mushroom' pattern of growth.

At this point, inspecting Figures 2 to 7 may provide an insight into the sectoral composition of the aggregate results.

As to Germany, Figure 2 (together with Table 1) shows that for 1995-2000 the role of subsystems *I:Transport-Comm.* and *N:Health* has been of importance to the aggregate development, but a very broad pattern can be observed. Among the most dynamic subsystems (those closer to the origin) we find *DG:Chemicals* and the *DK,DL,DM: Metals-Machinery* complex, together with *DM:Transport Equip.* This last subsystem has been of importance during the 2000-2005 period and, together with productivity growth of *G:Trade* and *K:Business Services*, account for a crucial part of overall labour saving, making the growth pattern more localised.

In contradistinction, in the case of France, from Figure 3 we read that the contribution of hyper-subsystems *G:Trade* and *K:Business Services* to ρ^* has been small or negative, while the role of *N:Health* and *I:Transport-Comm.*, together with a manufacturing core of subsystems including *DG, DK, DL, DM:*

Chemicals-Machinery-Transport Equip. (though altering positions between them) explains a substantial part of productivity growth. In any case, the pattern becomes progressively more broad and balanced.

Consider, instead, the transition dynamics of Italy, as displayed by Figure 4. A scenario of broad expansion with the exception of *K:Business Services*, *M:Education* and *N:Health* for the period 1995-2000 transforms into a 'mushroom' like pattern where *OP:Personal Services*, *K:Business Services*, *H:Hotel-Restaurant* and *G:Trade* suffer from sharp declines in productivity between 2000 and 2005. During this period, only a reduced subset of hyper-subsystems like *I:Transport-Comm.*, *DG:Chemicals* and *DJ,DK,DL:Metals-Machinery* have a mild labour saving performance. The pattern becomes notoriously localised, and overall productivity growth turns negative.

From Figure 5 we read that Japanese dynamics has been the exact opposite to the Italian one.[11] Japan experienced a transition from a 'mushroom' like pattern during 1995-2000 to a 'yeasty' like one during the 2000-2005 period. Between 1995 and 2000 labour saving trends of mainly *ABC:Primary*, *DA:Food-Tobacco*, *DK, DL, DM: Machinery-Transport Equip.* and *I:Transport-Comm.* accounted for nearly 40% of total employment and 100% of productivity gains, showing a localised pattern of growth. However, during 2000-2005, a notorious change in *G:Trade* and *K:Business Services* subsystems, together with *I:Transport-Comm.* and *J:Finance* have contributed to sharp labour saving trends that became broad and diffused throughout the economy.

The UK also experienced a transition from a 'mushroom' like pattern (1995-2000) to a 'yeasty' one (2000-2005), as can be seen from Figure 6. During the first period, *DL:Electr. Machinery*, *I:Transport-Comm.*, *J:Finance* and *N:Health* have mainly driven labour saving trends. While from the diagram it emerges that it takes almost 70% of total employment to reach the overall productivity growth ρ^* during

[11] Recall however the special status of Japan's labour saving trends, which occur in a context of employment destruction throughout the whole decade 1995-2005.

the 2000-2005 period, this number being less than 40% during the previous (1995-2000) period. Moreover, there are important changes in the dynamics of some subsystems as the transition occurs. For example, the change in *DA:Food-Tobacco*, *DG:Chemicals*, *G:Trade* and *K:Business Services* is noticeable.

Finally, the case of the US is displayed in Figure 7. Its 'mushroom' like pattern of 1995-2000 has been strongly influenced by the negative performance of hyper-subsystems *L: Public Admin.*, *OP:Personal Services* and *K:Business Services*. The counterbalancing trends of *G:Trade* (above all) together with the rest of service subsystems and *DL:Electr. Machinery* (the main producer of ICT technology) have resulted in a positive overall value for ρ^* (which would otherwise have been sharply negative). In fact, the transition into a 'yeasty' productivity growth pattern during 2000-2005 can be mainly explained by the 180 degree change in the labour saving trends of the three subsystems with worst productivity performance of the previous period (*K*, *L*, and *OP*).

4 Summary of findings and concluding remarks

From the application of Harberger diagrams to hyper-integrated labour productivity growth, a diversity of roles for different subsystems in different countries has been found. For example, the negative productivity development of *K:Business Services*, *OP:Personal Services* and *L:Public Admin.* in the US during 1995-2000 has been crucial to explain its 'mushroom' like pattern, and suggests a continuing outsourcing of 'sluggish' services by US manufacturing (as has been argued by, e.g. ten Raa and Wolff (2001)). However, this pattern has dramatically changed from 2000 to 2005, with *K:Business Services* becoming a leader subsystem as regards hyper-integrated labour saving trends.

As to the original conjectures Harberger had on the pattern of growth, they should be qualified according to the overall rhythm of productivity growth. Given that Harberger had the US in mind when making the characterisation described in section 2, his description (even for ρ^* instead of TFPG) fits well for the first sub period (1995-2000) explored in this paper. Less than 20% of total employment accounts for 100% of productivity growth, the winners and losers compensate each other, the main three losers (subsystems *K:Business Services*, *L:Public Admin.*, and *OP:Personal Services*) have been of importance to explain the overall result and the relative position of leaders in productivity performance changed between periods.

However, as soon as there have been transitions to a high(er) productivity growth path (not only in the US, but also in Japan and the UK), the growth pattern has become 'yeasty', with more than 60% (for the UK) and 80% (for the US and Japan) of total employment accounting for 100% of the productivity gains. And precisely the opposite has occurred in the case of Italy, which by sharply reducing its value of ρ^* made a transition into a 'mushroom' like pattern. Hence, a high productivity growth regime (as measured by ρ^*) seems to be more compatible with a less uneven pattern of technological development, at least during the 1995-2005 period for the six economies analysed.[12]

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[12] This result is in accordance (though referring to ρ^* rather than to TFP Growth) with one of the main findings of Inklaar and Timmer (2007, p. 182): "there is an almost perfect negative correlation between aggregate growth and the area underneath the Harberger diagram. In other words, higher TFP growth also means more balanced TFP growth".

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