Selecting efficient techniques: private versus social standpoint*

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Abstract

Empirical analysis has widely demonstrated that real world activities are rarely on their production frontier. Hence, an obvious concern arises towards the selection and implementation of efficient techniques. The paper suggests that a suitable approach to address this issue at the sector level should account for interindustry transactions. It argues that, once linkages across sectors are taken into account, a natural distinction arises between the social and private standpoints in the selection of efficient activities at the sector level. The paper suggests a system approach to the selection of social efficient techniques at the sector level. Such an approach makes shadow prices reflect the *minimum* marginal costs, thus reconciling the two standpoints. The analysis is relevant to policy makers or regulators (e.g. EU authorities aiming at setting sectorial benchmarks) since it defines the conditions under which a sectorial private approach may fail to achieve social efficiency and those under which it may even reduce its current level. Empirical analysis confirm that the sectorial private approach may lead to the identification of misleading benchmarks and may even lower the overall efficiency level.

KEYWORDS: Efficiency, Firm Behavior, Input-Output Models, Regulation

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1. Introduction

This paper deals with the choice of efficient techniques in productive sectors. Empirical analysis has widely demonstrated that real world activities or sectors are rarely on their production frontier.[1] Such inefficiencies affect the welfare of the entire economy, particularly in the case of public utility sectors. There is therefore an obvious concern towards the selection and implementation of efficient techniques.[2]

We argue that the current practice may provide misleading results because it rests on a concept of efficiency based on the implicit assumption that each sector is isolated from the rest of the economy. Alternatively, if interactions with other sectors are recognised, the underlying assumption is that they are not affected by the inefficiencies present in the entire system (including the ones in the sector under evaluation).[3]

The paper argues that an approach accounting simultaneously for interindustry linkages and sectorial inefficiencies leads to the distinction between social and private standpoints. From a social point of view, efficient techniques at the sector level minimise the cost of both direct and indirect primary input absorption. From a private point of view, conversely, the objective at the sector level is to minimise primary and intermediate inputs cost, given primary and intermediate inputs prices.

The distinction between social and private point of view may arise because (distorted) intermediate inputs prices reflect sectorial inefficiencies and transmit them from sector to sector. Of course, in a perfectly competitive world, where all firms lie on the frontier and intermediate inputs prices correctly reflect the *minimum* marginal costs of production, privately efficient techniques are also efficient from the social point of view. However, in our less than perfect world inefficiencies exist and are spread around by interindustry relationships.

[1] See among others Atkinson and Kerkvliet (1989), Färe, Grosskopf and Nelson (1990), Ferrier and Lovell (1990), Grosskopf, Hayes and Hirschberg (1995), Blank (2000).

[2] The importance of identifying best practices in order to increase competitiveness and efficiency is emphasised also at the EU level. The European Commission, indeed, claims that there is the need of identifying 'the key areas of competitiveness to which benchmarking could be applied to measure performance and to identify best practices in order to improve efficiency' European Commission (1999b). See also European Commission (1998) and (1999a).

[3] This approach is followed, for example, in the *OECD Report on regulatory reform* (1997) that evaluates the impact of regulatory reforms in different countries. Such report first considers the effect of reforming each single sector separately, and then it aggregates all such effects and assesses their impact on the whole economy. Also the *price-cap* regulation (see on this Armstrong and Cowan (1994)), which sets a roof on the increase of the price level of regulated sectors output, neglects interindustry linkages.

The paper suggests a consistent operational criterion for the selection of social efficient activities in a framework accounting for interindustry linkages. By consistent we mean that such a criterion should make social and private standpoints coincide in a perfectly competitive world, while it should allow a quantitative assessment of the differences between the two perspectives, whenever they arise.

An empirical analysis performed on a set of OECD interindustry data shows that the difference between the two standpoints is empirically relevant both in terms of the amount of inefficiency not captured by the private approach and in terms of 'wrong' selection of activities. More precisely, in most cases the social inefficiency of a given sector is largely due to inefficiencies imported from the economic system *via* distortions of intermediate inputs prices.

Because of these real world imperfections, the private approach may lead to the selection of socially inefficient techniques and therefore policy implications relevant to sectorial regulators or policy makers may arise. Two points are worth emphasizing. The first one concerns the identification of sectorial benchmarks.[4] In order to be socially relevant, such benchmarks should be selected on the basis of intermediate inputs (shadow) prices reflecting their *minimum* marginal cost of production, as derived by the above criterion, based on a system approach. The current practice, however, may provide misleading results because it refers either to prices reflecting the *observed* marginal costs or to the observed market prices.

The second issue concerns the conditions under which a sectorial private approach may not only fail to achieve social efficiency but may even lower the current level of social efficiency. We first show that any approach to sectorial efficiency resting upon intermediate inputs prices reflecting their *observed* marginal costs of production improves (does not decrease) the current (social) efficiency level. Then, we show that, on the contrary, if prices embed some degree of market power, the implementation of privately efficient techniques in some sectors may even decrease the level of social efficiency. In such a case, therefore, the prescriptions of sectorial regulators may be detrimental to the system as a whole.

The rest of the paper is organised as follows. The next section introduces the notation and the technology assumptions. Section 3 discusses how intersectorial linkages spread existing inefficiencies *via* intermediate inputs prices. Section 4 suggests a system approach to a social assessment of sectorial efficiency and demonstrates its consistency. Moreover, it shows the conditions under which the implementation of privately efficient techniques allows to improve (not worsen) the current situation. Section 5 presents and discusses the results of the empirical application. Section 6 draws the conclusions.

[4]See, e.g., European Commission (1999a) and (1999b).

2. Technology assumptions

Let K economic systems be composed by N sectors. Sector j of country k, for $j = 1, ..., N$ and $k = 1, ..., K$, is assumed to produce just one output,[5] denoted by $u_j^k \in \Re_+$, using M primary (imported and non imported) inputs, and N intermediate inputs, denoted respectively as $x_j^k \in \Re_+^M$ and $a_j^k \in \Re_+^N$. Then, for country k, $a^k = \begin{pmatrix} a_1^k & \cdots & a_N^k \end{pmatrix}$ is the interindustry transaction matrix, and $u^k = \begin{pmatrix} u_1^k & \cdots & u_N^k \end{pmatrix} \in \Re_+^N$ is the economy wide output vector. The sectorial input-output vector of country k will be shortly denoted[6] by $s_j^k \in \Re^{1+N+M}$, for $j = 1, ..., N$, where

$$s_j^k = \begin{pmatrix} u_j^k \\ -a_j^k \\ -x_j^k \end{pmatrix} \tag{2.1}$$

We further denote the final demand of sector j by d_j^k, the outputs (and intermediate inputs) observed market prices by $p^k = \begin{pmatrix} p_1^k & \cdots & p_N^k \end{pmatrix} \in \Re_+^N$, and the primary inputs observed prices by $w^k = \begin{pmatrix} w_1^k & \cdots & w_M^k \end{pmatrix} \in \Re_+^M$.

In general, for sector j, the input correspondence $L_j : \Re_+ \rightarrow L_j(u_j^k) \subseteqq \Re_+^{N+M}$ maps output $u_j^k \in \Re_+$ into subsets $L_j(u_j^k)$ of input vectors $(a_j, x_j) \in \Re_+^{N+M}$. The production technology of this sector has the following cost function:

$$C^*(u_j^k, w, p) = \min_{a_j, x_j} \left\{ \left(p^k a_j + w^k x_j \right) : (a_j, x_j) \in L_j(u_j^k) \right\} \tag{2.2}$$

where,

$$L_j(u_j^k) = \left\{ (a_j, x_j) \in \Re_+^{N+M} : (a_j, x_j) \text{ can produce } u_j^k \right\} \tag{2.3}$$

The set $L_j(u_j^k)$ includes all the input vectors that yield at least the output level u_j^k. We assume that the set $L_j(u_j^k)$ is convex, closed and satisfies monotonicity (see Färe, Grosskopf and Lovell, (1994)).

In particular, in the empirical applications, we will assume that the input set boundary (the isoquant) may be well approximated by a 'best practice' frontier constructed as a convex piecewise linear envelopment of the data. Therefore, for country k, we define the estimate of sector j input set $L_j(u_j^k)$ as follows:

$$\hat{L}_j(u_j^k) = \left\{ (a_j, x_j) \in \Re_+^{N+M} : \begin{pmatrix} s_j^1 & \cdots & s_j^K \end{pmatrix} z \geq \begin{pmatrix} u_j^k \\ -a_j \\ -x_j \end{pmatrix}, z \in \Re_+^K \right\} \tag{2.4}$$

[5] We assume, consistently with the input-output approach, no joint production and no alternatives techniques.

[6] Hencefoth superscript k will denote the current variable of country k.

We assume constant returns to scale and free disposability of all inputs. The constant return to scale assumption is implied by the fact that we are considering as feasible any production plan resulting from the expansion or contraction of any observed production plan. The constant return to scale and the convexity assumptions imply that the production set is a convex cone.

3. Social and private points of view in aggregate and sectorial efficiency measures

Consider a simple world where K economies produce two purely final goods using one intermediate input and one primary input. We can represent these economies as follows,[7]

$$\begin{aligned} \widehat{u}^k - a^k &= \begin{bmatrix} u_1^k & 0 & 0 \\ 0 & u_2^k & 0 \\ -a_{31}^k & -a_{32}^k & u_3^k - a_{33}^k \end{bmatrix}, \qquad d^k = \begin{bmatrix} d_1^k \\ d_2^k \\ 0 \end{bmatrix} \\ x^k &= \begin{bmatrix} -x_1^k & -x_2^k & -x_3^k \end{bmatrix} \end{aligned}$$

for $k = 1, ..., K$. Let us start by considering each system as a whole macroeconomic system. Its technological relationships may be summarized by the implicit function $F(u_1^k, u_2^k, , u_3^k, x_A^k) = 0$, where $x_A^k = \sum_i x_i^k$. The efficient aggregate production plan of country k solves the following optimisation problem:

$$C^*(u^k, w^k) = \min_{x_A} \left\{ w^k x_A : x_A \in L(u^k) \right\} \tag{3.1}$$

where,

$$L(u^k) = \left\{ x_A \in \Re_+ : x_A \text{ can produce } u^k \in \Re_+^3 \right\} \tag{3.2}$$

Under the hypothesis that the input set is approximated as in (2.4), this is the well-known DEA model.[8] The solution x_A^* minimises the total cost of primary input, given the primary input price and the minimum amount of outputs to be produced.

Now let us turn to the evaluation of the efficiency of a particular sector, say sector 1. In this case the total sectorial cost include the cost of intermediate inputs (in our simple case the cost of input 3):

$$C^*(u_1^k, w^k, p_3^k) = \min_{a_{31}, x_1} \left\{ \left(p_3^k a_{31} + w^k x_1 \right) : (a_{31}, x_1) \in L_1(u_1^k) \right\} \tag{3.3}$$

[7] Henceforth $\widehat{y}$ will denote the diagonalisation of vector y.

[8] For an extensive discussion of DEA models see Färe, Grosskopf, and Lovell (1994).

where $L_1(u_1^k)$ is as defined in (2.3). We want to argue that this formulation is well suited only for privately oriented, as opposed to socially oriented, choices, in the sense that it may fail to the minimise the total cost of the primary input absorbed in the economy.

The argument runs as follows. The solution vector $\begin{bmatrix} u_1^k & -a_{31}^{*k} & -x_1^{*k} \end{bmatrix}$ is the production plan that minimises sector 1 production cost as a function of primary and *intermediate* inputs prices, in this case w^k and p_3. If p_3 equals the marginal cost of production, then

$$p_3 = w^k \xi_3^k \left[1 - \alpha_{33}^k\right]^{-1} \tag{3.4}$$

where α_{ij}^k's and ξ_j^k's are entries of the intermediate inputs coefficient matrix $\alpha^k = a^k \times \left(\widehat{u}^k\right)^{-1}$ and of the primary inputs coefficient vector $\xi^k = x^k \times \left(\widehat{u}^k\right)^{-1}$.[9]

Equation (3.4) shows that the less efficient is sector 3, the higher is the marginal cost of producing u_3^k and therefore the higher is its price. Such a biased price, in turn, affects the choice of the optimal production plan which solves (3.3).

The inconsistency between social and private approach arises because the sectorial problem on the one hand minimises the cost of *directly* absorbed primary inputs, while, on the other hand, it keeps the amount of *indirectly* absorbed primary inputs constant.[10] In other words, on the one hand it chooses the sectorial optimum and on the other hand it takes the sectorial *current* technique as the best one.

In order to clarify the point it may be useful to think at it in the standard terms of a two dimensional isoquant in the input space. Add a straight line r representing the objective function. The choice of the optimal technique obviously depends on the slope $-\frac{w}{p_3}$ of r. If the slope is 'distorted', then a 'wrong' technique is selected.

It is evident that the rationale of problem (3.1) and the rationale of problem (3.3) differ substantially. The former relies on a collective point of view (social point of view), while the latter is based on a private 'sector manager' point of view. We can therefore define two different concepts of efficient production plan of a sector.

Definition 3.1. *Socially efficient production plans are chosen according to non*

[9] The general price-cost equation is $p = (1+\widehat{\mu})\, w\xi^k \left[I - (1+\widehat{\mu})\, \alpha^k\right]^{-1}$, where $\mu = \begin{pmatrix} \mu_1 & \mu_2 & \mu_3 \end{pmatrix}$ and μ_i is the markup on the marginal cost of the i^{th} good. The price-cost equation (3.4) assumes zero markups. It is worth emphasizing that, in the general case, *each* price depends on the techniques of *all* sectors.

[10] It is worth noting that the same problem arises in sectorial efficiency evaluations based on vertically integrated sectors, since the inefficiencies embodied from other sectors, through the vertical integration process, cannot be fixed anymore.

distorted intermediate inputs prices $\tilde{p}^k$*, still to be defined, which reflect the* minimum *marginal costs, i.e.*

$$\left(\tilde{a}_j^*, \tilde{x}_j^*\right) = \arg\min_{a_j, x_j} \left\{ \left(\tilde{p}^k a_j + w^k x_j\right) : (a_j, x_j) \in L_j(u_j^k) \right\} \tag{3.5}$$

Definition 3.2. *Privately efficient techniques are selected on the basis of distorted intermediate inputs prices* $p^k \neq \tilde{p}^k$*, i.e.*

$$\left(a_j^*, x_j^*\right) = \arg\min_{a_j, x_j} \left\{ \left(p^k a_j + w^k x_j\right) : (a_j, x_j) \in L_j(u_j^k) \right\} \tag{3.6}$$

We call the former choice criterion *socially* efficient, since it will be shown that, if all sectors follow it, it leads to the economy wide minimisation of primary inputs costs.

From these definitions two efficiency concepts arise in a natural way. A social one:

$$\widetilde{eff}_j^* = \frac{\widetilde{C}^*(u_j^k, w^k, \tilde{p}^k)}{C(u_j^k, w^k, p^k)} \tag{3.7}$$

and a private one:

$$eff_j^* = \frac{C^*(u_j^k, w^k, p^k)}{C(u_j^k, w^k, p^k)} \tag{3.8}$$

where $C^*(u_j^k, w^k, p^k) = \left(p^k a_j^* + w^k x_j^*\right)$ is the sectorial *private* minimum cost, derived from problem (3.6), and $\widetilde{C}^*(u_j^k, w^k, \tilde{p}^k) = \left(\tilde{p}^k \tilde{a}_j^* + w^k \tilde{x}_j^*\right)$ is the sectorial *social* minimum cost, which derives from problem (3.5) and minimises both *direct and indirect* absorption of primary inputs in the sector under examination.

4. Socially efficient techniques at the sectorial level

How to choose, in a given sector, the efficient technique consistently with the social point of view? From the above discussion it is evident that the selection criterion should include as choice variables the interindustry relationships from which price distortions may arise. In order to do this, the input set, for country k, needs to be defined as follows:

$$\mathcal{I}(d^k) = \left\{ (a, x) \in \Re_+^{N \times (N+M)} : (a, x) \text{ can produce } \sigma : \sigma = d^k + \sum\nolimits_j a_j \right\} \tag{4.1}$$

where $\sigma \in \Re^N$.

The condition that in (2.3) imposes to produce a certain amount of gross output is replaced by $\sigma = d^k + \sum_j a_j$, which states that the gross production σ is endogenously determined and must satisfy both the final demand and the demand for intermediate inputs. The intermediate inputs demand is therefore a choice variable constrained to satisfy the interindustry relationships. Notice that according to this formulation the selection of the efficient technique in one sector must proceed *pari passu* with the selection of the efficient techniques in other sectors. The gross production σ that satisfies the final demand is unknown. This is the reason why the input set must be defined on the final demand vector d^k rather than on the gross production vector u^k.

The economy wide cost function is therefore the following:

$$\widetilde{C}^*(d^k, w^k) = \min_{\{a,x\}} \left\{ \sum_{j=1}^{N} w^k x_j : (a,x) \in \mathcal{I}(d^k) \right\} \tag{4.2}$$

Under the assumption that the input set boundary may be approximated by a convex piecewise linear 'best practice' frontier, $\mathcal{I}(d^k)$ may be estimated by the following set:

$$\mathcal{T}(d^k) = \left\{ (a,x) \in \Re_+^{N\times(N+M)} : S^k \begin{bmatrix} z_1 \\ \vdots \\ z_N \end{bmatrix} \geq \sigma, z_j \in \Re_+^K \ \forall j \right\} \tag{4.3}$$

where

$$\begin{aligned} S^k &= \begin{bmatrix} s_1^1 & \cdots & s_1^K & 0 & \cdots & 0 & \cdots & 0 & \cdots & 0 \\ 0 & \cdots & 0 & s_2^1 & \cdots & s_2^K & \cdots & 0 & \vdots & 0 \\ 0 & \cdots & 0 & 0 & \cdots & 0 & \cdots & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & \cdots & 0 & 0 & \cdots & 0 & \cdots & s_N^1 & \cdots & s_N^K \end{bmatrix} \\ \sigma_j &= \begin{bmatrix} d_j^k + \sum_{i=1}^N a_{1i} \\ -a_j \\ -x_j \end{bmatrix} \end{aligned}$$

s_j^k is the observed sector j input-output vector of country k as defined in (2.1) and $0 \in \Re^{1+N+M}$. The estimated economy wide cost function is the following:

$$\widetilde{C}^*_{\mathcal{T}}(d^k, w^k) = \min_{\{a,x\}} \left\{ \sum_{j=1}^{N} w^k x_j : (a,x) \in \mathcal{T}(d^k) \right\}$$

This is a DEA model that accounts for intersectorial linkages.

Problem (4.2) looks simultaneously for the production plans of all sectors so that the economy wide primary inputs cost is minimised. In other words, it looks for the 'efficient economic system', which produces the smallest amount of gross production consistent with the final demand vector, while determining the *optimal* quantities of intermediate inputs. Both *direct and indirect* absorption of primary inputs result to be minimised. For this reason the solution to problem (4.2) represents a socially efficient economic system. From now on we occasionally refer to problem (4.2) as the economy wide approach to social efficiency (as opposed to the sectorial approach to social efficiency of definition 3.1).

The Lagrange multipliers associated to problem (4.2), denote them by $\lambda^* \in \Re^N_+$, reflect the *minimum* marginal costs. The relevance of such variables is related to the intermediate inputs prices. As observed at the beginning, the inconsistency between social and private standpoints in the selection of efficient techniques at the sector level arises from intermediate inputs prices distortions. Shadow prices $\tilde{p}^k \equiv \lambda^*$ allow to amend the sectorial selection of socially efficient techniques from these distortions.

Proposition 4.1. *The price vector $\tilde{p}^k$ supports as a solution of the following sectorial problem,*[11]

$$\min_{a_j, x_j} \left\{ \left(\tilde{p}^k a_j + w^k x_j \right) : (a_j, x_j) \in L_j(\tilde{\sigma}_j^{*k}) \right\} \tag{4.4}$$

the production plan $\left(\tilde{a}_j^*, \tilde{x}_j^*\right)$, which is (part of) the solution of problem (4.2).

Proof. We will prove the above proposition assuming that the input sets boundaries are smooth. We will show that, for sector j, the solution to the general problem (4.2), namely $\left(\tilde{a}_j^*, \tilde{x}_j^*\right)$, satisfies the first order conditions of problem (4.4).[12] In order to do this, we need to show that the choice sets of the two problems coincide and then characterise the FOCs of both problems.

First, notice that the economy wide input set $\mathcal{I}(d^k)$ is equal to the Cartesian product of appropriately defined sectorial inputs set, i.e. $\mathcal{I}(d^k) = L_1(d_1^k) \times ... \times L_N(d_N^k)$ where $\mathcal{I}(d^k) \subseteq \Re_+^{N\times(N+M)}$ is as defined in (4.1) and $L_j(d_j^k) \subseteq \Re_+^{N+M}$ is

[11] Notice that, in order to ease the comparison with problem (4.2), we have set the gross production to be equal to σ_1^{*k}. Because of the constant returns to scale assumption, this modification does not change the optimal production plan.

[12] The second order conditions are satisfied by assumption since we assume that input sets are convex.

defined as:

$$L_j(d_j^k) = \left\{ (a_j, x_j) \in \Re_+^{N+M} : (a_j, x_j) \text{ can produce } \sigma_j : \sigma_j = d_j^k + \sum_i a_{ji} \right\}$$

for $j = 1, ..., N$.

Problem (4.2) can be restated as follows,

$$\begin{aligned} & \min_{a,x} \sum_{j=1}^{N} w^k x_j \\ & s.t. \\ F_1(a_1, x_1) \geq \; & d_1^k + \sum_{i=1}^{N} a_{1i} \\ & \vdots \\ F_N(a_N, x_N) \geq \; & d_N^k + \sum_{i=1}^{N} a_{Ni} \\ a_j \geq \; & 0 \;\; \forall j \\ x_j \geq \; & 0 \;\; \forall j \end{aligned} \tag{4.5}$$

where $F_j(a_j, x_j)$ is a quasi-concave production function embodying the sectorial technological relationships of the input set $L_j(u_j^k)$, i.e. $F_j(a_j, x_j) \geq u_j^k \Leftrightarrow (a_j, x_j) \in L_j(u_j^k)$. The Lagrangian of this problem is as follows:

$$\mathcal{L} = \sum_{j=1}^{N} \left[w x_j - \lambda_j \left(F_j(a_j, x_j) - d_j^k - \sum_{i=1}^{N} a_{ji} \right) \right]$$

the FOCs with respect to x_{ij} and a_{ij} imply that at the optimum it must be:

$$w_i^k \geq \lambda_j^* \frac{\partial F_j\left(\widetilde{a}_j^*, \widetilde{x}_j^*\right)}{\partial x_{ij}} \text{ and } \widetilde{x}_{ij}^* \left[w_i^k - \lambda_j^* \frac{\partial F_j\left(\widetilde{a}_j^*, \widetilde{x}_j^*\right)}{\partial x_{ij}} \right] = 0 \tag{4.6}$$

$$\lambda_i^* \geq \lambda_j^* \frac{\partial F_j\left(\widetilde{a}_j^*, \widetilde{x}_j^*\right)}{\partial a_{ij}} \text{ and } \widetilde{a}_{ij}^* \left[\lambda_i^* - \lambda_j^* \frac{\partial F_j\left(\widetilde{a}_j^*, \widetilde{x}_j^*\right)}{\partial a_{ij}} \right] = 0 \tag{4.7}$$

$j = 1, ..., N$ and $i = 1, ..., N$.

The sectorial problem (4.4), in turn, may be restated as follows

$$\begin{aligned} & \min_{a_j, x_j} w^k x_j + \widetilde{p}^k a_j \\ & s.t. \\ F_j(a_j, x_j) \geq \; & d_j^k + \sum_{i=1}^{N} \widetilde{a}_{ji}^* \\ a_j \geq \; & 0 \\ x_j \geq \; & 0 \end{aligned} \tag{4.8}$$

where $\widetilde{p}^k = \lambda^*$, i.e. the intermediate inputs prices are set equal to the Lagrange multipliers associated to the solution of (4.5).[13] Then

$$\mathcal{L}_j = w^k x_j + \widetilde{p}^k a_j - \mu_j \left(F_j(a_j, x_j) - d_j^k - \sum_{i=1}^{N} \widetilde{a}_{ji}^* \right)$$

in this case, the FOCs with respect to x_{ij} and a_{ij} imply that at the optimum:

$$w_i^k \geq \mu_j^* \frac{\partial F_j\left(\widehat{a}_j^*, \widehat{x}_j^*\right)}{\partial x_{ij}} \text{ and } \widehat{x}_j^* \left[w_i^k - \mu_j^* \frac{\partial F_j\left(\widehat{a}_j^*, \widehat{x}_j^*\right)}{\partial x_{ij}} \right] = 0 \tag{4.9}$$

$$\widetilde{p}_i^k \geq \mu_j^* \frac{\partial F_j\left(\widehat{a}_j^*, \widehat{x}_j^*\right)}{\partial a_{ji}} \text{ and } \widehat{a}_j^* \left[\widetilde{p}_i^k - \mu_j^* \frac{\partial F_j\left(\widehat{a}_j^*, \widehat{x}_j^*\right)}{\partial a_{ji}} \right] = 0 \tag{4.10}$$

since $\widetilde{p}_i^k = \lambda_i^*$ the vector $\left(\widetilde{a}_j^*, \widetilde{x}_j^*\right)$ that solves (4.6) and (4.7) must also solve (4.9) and (4.10), i.e. $\left(\widehat{a}_j^*, \widehat{x}_j^*\right) \equiv \left(\widetilde{a}_j^*, \widetilde{x}_j^*\right)$. ■

This proposition guarantees the internal consistence of the methodology. Whatever the approach, be it sectorial as in (4.4) or economy wide as in (4.2), the efficient technique for sector j results to be the same once the right prices are used in each sector.

Notice also that shadow prices are equal to the prices calculated by applying the price-cost equation to the efficient economic system derived as a solution of (4.2).[14]

[13] Any gross production level, other than $d_j^k + \sum_{i=1}^{N} \widetilde{a}_{ji}^*$, would also be appropriate because of the constant return to scale assumption.

[14] A proof of this equality, for the piecewise linear case, is provided in an appendix available upon request. This result is a direct consequence of the input-output assumption of no joint production. In the more general case, though prices cannot be derived from the input-output price-cost equation, shadow prices of problem (4.2) still help to rightly select efficient activities at the sectorial level.

4.1. Constrained economies and suboptimal choices

The above criterion may be readily extended to the case where rigidities affect (part of) the economy, preventing some sectors to change the production techniques (but not the production levels and prices).

In order to select socially efficient production plans in the 'flexible' sectors, one needs to include the existing rigidities as constraints in the economy wide input set (4.1). Let $\mathcal{H}$ be the set of sectors affected by rigidities, then the input set may be redefined as follows:

$$\mathcal{G}(d^k) = \left\{ \begin{array}{c} (a,x) \in \Re^{N\times(N+M)} : (a,x) \text{ can produce } \sigma : \sigma = d^k + \sum_j a_j \\ (a_j, x_j) = \rho_j \left(a_j^k, x_j^k\right), \ \rho_j \in \Re_+, \text{ for all } j \in \mathcal{H} \end{array} \right\}$$

where $\sigma \in \Re^N$. The input set $\mathcal{G}(d^k)$ is analogous to $\mathcal{I}(d^k)$ defined in (4.1), except that the techniques of sectors belonging to $\mathcal{H}$ cannot be altered (just scaled up or down, according to the scalar ρ_j, to adjust quantities). In this case, the socially efficient techniques solve the following problem, which is a constrained version of (4.2).

$$\widetilde{C}^*_{\mathcal{G}}(d^k, w^k) = \min_{\{a,x\}} \left\{ \sum_{j=1}^{N} w^k x_j : (a,x) \in \mathcal{G}(d^k) \right\} \tag{4.11}$$

The production plans that solve problem (4.11) minimise the total cost of primary inputs, given the constraints affecting part of the system.

The issue that we want to explore concerns the consequences of departing from such criterion in the selection of the efficient production plans in the 'flexible' sectors.

Proposition 4.2. *Suppose that some sectors are affected by rigidities and therefore cannot amend their inefficiencies by changing their production techniques (while they are able to adjust their production levels and prices), then:*

- *if intermediate inputs prices reflect the* observed marginal costs *of production, the implementation of privately efficient techniques (Definition 3.2) in the amendable sectors cannot worsen the overall efficiency level, in the sense that the primary inputs total cost cannot increase.*
- *if the intermediate inputs prices embed market power (possibly) present in some sectors, the implementation of privately efficient techniques in the 'flexible' sectors may lower the overall efficiency level.*

The first part of the proposition will be proved analytically. The second one by counter examples provided in the next section.

Proof. Suppose without loss of generality that $\mathcal{H}$ includes all but one sectors (say sector 1) and recall also that we assume that intermediate inputs prices reflect the current marginal cost of production. Denote by $\left(a_j^k, x_j^k\right)$ for $j = 1, ..., N$ the current (possibly inefficient) techniques and by $(\widehat{a}_1^*, \widehat{x}_1^*)$ sector 1 privately optimal choice based on intermediate inputs prices.[15]

Let us start by considering the current (inefficient) situation. Notice that, when the intermediate inputs prices reflect the current marginal costs of production, at the current production plans all sectors make zero profits. This is equivalent to saying that, in an interindustry framework, the total primary inputs cost must coincide with the value of the final demand, evaluated at prices that equal marginal costs, since intermediate transactions cancel out. Hence

$$\sum_{j=1}^{N} w^k x_j^k = \sum_{j=1}^{N} \lambda_j d_j^k$$

where λ_j, for $j = 1, ..., N$, denotes sector j current marginal cost.

Now, let us denote by $\widehat{\lambda}_j^*$, for $j = 1, ..., N$, sector j marginal cost in the economy where sector 1 implements the production technique $(\widehat{a}_1^*, \widehat{x}_1^*)$ while the other sectors must keep on with their current technique (adjusting only their production levels and prices). Then, clearly $\widehat{\lambda}_j^* \leq \lambda_j$ for all j, since marginal costs cannot increase when a single sector minimise its costs. Thus

$$\sum_{j=1}^{N} \widehat{\lambda}_j^* d_j^k \leq \sum_{j=1}^{N} \lambda_j d_j^k$$

which implies that

$$w^k \widehat{x}_1^* + \sum_{j \neq 1} \rho_j w^k x_j^k \leq \sum_{j=1}^{N} w^k x_j^k \tag{4.12}$$

where ρ_j is the scalar according to which sector j adjusts its production level. Inequality (4.12) states that implementing the privately efficient technique in the first sector cannot increase the total primary inputs cost, i.e. it cannot lower the overall social efficiency. The second part will be proven in the next section. ■

[15] The minimising bundle $(\widehat{a}_1^*, \widehat{x}_1^*)$ is such that the sectorial FOCs (4.9) and (4.10) are satisfied. If $(\widehat{a}_1^*, \widehat{x}_1^*) \neq \left(a_1^k, x_1^k\right)$ then at the current prices sector 1 makes positive profits.

5. Empirical analysis

In this section, the two approaches, private and social, are compared. Social and private efficiency levels of 5 OECD countries are assessed by exploiting the OECD input-output tables, which are aggregated in 15 homogeneous sectors.[16]

This application is meant to assess the relevance of price distortions in creating and spreading inefficiencies across sectors, thus widening the difference between the two approaches. We solve, for each country, the economy wide problem (4.2) approximating $\mathcal{I}(d^k)$ with $\mathcal{T}(d^k)$. In this way we are able to get, for each sector, the socially efficient production plan and the social efficiency measure as defined in (3.7). We compare both of them with the production plans and the efficiency measures which result from the private approach,[17] defined by problem (3.6).

sector/countries	**canada**	**france**	**denmark**	**germany**	**UK**
AGR	0,70	0,71	1,00	0,69	0,74
FOD	0,95	1,00	0,90	0,91	0,96
TEX	1,00	0,85	0,80	0,78	0,80
CHE	0,87	1,00	0,93	1,00	0,97
MID + MNM	0,47	1,00	0,80	0,69	0,77
BMI + MEQ	0,93	1,00	0,87	0,97	0,93
WOD + PAP + MOT	0,84	0,93	0,91	1,00	0,80
EGW	0,70	0,75	1,00	0,90	0,80
CST	1,00	0,75	0,81	0,98	0,79
RWH	0,83	1,00	0,95	0,65	0,62
HOT	0,96	0,85	0,97	0,66	0,93
TAS	0,69	0,74	0,58	0,64	1,00
COM	0,74	0,53	1,00	0,77	0,61
FNS	0,97	0,92	0,93	1,00	0,52
RES + SOC + PGS + OPR	0,54	0,57	1,00	0,75	0,79

Figure 5.1: Private efficiency

Tables (5.1) and (5.2) present the estimation of social and private efficiency measures. Social efficiency is everywhere largely different from private efficiency. Such difference may be meaningfully interpreted in light of inefficiencies stemming inside the sector and inefficiencies imported from other sectors. In fact sector j social efficiency may be decomposed as follows

$$\widetilde{eff}_j^* = \frac{\widetilde{C}^*(u_j^k, w^k, \widetilde{p}^k)}{C(u_j^k, w^k, p^k)} = \frac{C^*(u_j^k, w^k, p^k)}{C(u_j^k, w^k, p^k)} \frac{\widetilde{C}^*(u_j^k, w^k, \widetilde{p}^k)}{C^*(u_j^k, w^k, p^k)} = eff_j^* \times dis_j \qquad (5.1)$$

[16] Details about the input-output tables, their aggregation and comparability are provided in appendix A.

[17] In the private approach we assume that the intermediate inputs prices reflect the *current* marginal costs of production and that the set $L_j(u_j^k)$ may be approximated by $\hat{L}_j(u_j^k)$.

sector/countries	**canada**	**france**	**denmark**	**germany**	**UK**
AGR	0,36	0,46	0,88	0,46	0,49
FOD	0,43	0,57	0,78	0,53	0,59
TEX	0,53	0,47	0,63	0,49	0,49
CHE	0,38	0,73	0,77	0,70	0,67
MID + MNM	0,32	0,83	0,74	0,58	0,64
BMI + MEQ	0,58	0,74	0,74	0,77	0,67
WOD + PAP + MOT	0,46	0,61	0,80	0,76	0,55
EGW	0,47	0,56	0,94	0,76	0,64
CST	0,50	0,47	0,69	0,70	0,53
RWH	0,50	0,65	0,85	0,50	0,48
HOT	0,54	0,53	0,88	0,46	0,65
TAS	0,35	0,42	0,49	0,44	0,69
COM	0,57	0,42	0,97	0,69	0,52
FNS	0,53	0,52	0,89	0,75	0,39
RES + SOC + PGS + OPR	0,48	0,52	0,99	0,71	0,74

Figure 5.2: Social efficiency

The first term, namely eff_j^*, is just the private efficiency measure (as defined in (3.8)) and appraises sector j ability to choose the input mix that minimise costs, given prices. The second term, namely dis_j, is the ratio of the minimum *social* cost to the minimum *private* cost. Thus, it accounts for the share of social sectorial (in)efficiency imported from the rest of the economy *via* price distortions. Sector j is efficient from the social point of view if it satisfies two requisites: it is privately efficient (i.e. it minimises costs given prices) and do not import distortions from the rest of the economy (i.e. there are no inefficiencies in the economy that distort prices).

Comparing tables (5.1) and (5.2) it is clear that imported inefficiency affects all sectors across the 5 economies, though in different amounts. Notice the counter intuitive result: sectors cannot be divided into those importing and those exporting inefficiencies. Because of roundaboutness each sector is affected by any inefficiency arising in the economy and, in turn, its inefficiency affects all other sectors. It is worth emphasizing that the difference is not simply due to a rescaling of the inefficiency indexes. The *peers*, that is the countries that shape the best practice frontier, (may) change across the two points of view (see table (5.3)). Thus, the approach followed is not neutral in identifying the benchmarks against which performances have to be compared.

Notice also that, at face value, it may seem desirable from the social standpoint to increase eff_j^*. Indeed the benefits of an increase in eff_j^*, due to a change of production technique, may be offset by a decrease of dis_j due to a change in the intermediate inputs prices.

PEERS	CAN		DK		FR		GER		UK	
	Private	Social	Private	Social	Private	Social	Private	Social	Private	Social
Agriculture	FR	FR	FR	FR	FR	FR	FR	FR	FR	FR
Food	DK	DK	DK	DK	DK	DK	DK	DK	DK	DK
Textile	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN
Chemical	GER	GER	**DK**	**GER**	GER	GER	**GER**	**DK**	GER	GER
Mid + Mnm	DK	DK	DK	DK	DK	DK	DK	DK	DK	DK
Bmi + Meq	**DK**	**CAN**	DK	DK	**GER**	**DK**	**DK**	**GER**	CAN	CAN
Wood Paper Other	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER
Electr. Gas Water	FR	FR	**GER**	**FR**	FR	FR	FR	FR	FR	FR
Constructions	CAN	CAN	**GER**	**CAN**	CAN	CAN	CAN	CAN	CAN	CAN
Retail Wholesale	DK	DK	DK	DK	DK	DK	DK	DK	DK	DK
Hotels restaurants	**FR**	**CAN**	**FR**	**CAN**	CAN	CAN	**FR**	**CAN**	FR	FR
Transports	UK	UK	UK	UK	UK	UK	UK	UK	UK	UK
Communications	FR	FR	FR	FR	FR	FR	FR	FR	FR	FR
Financial insurance	**GER**	**CAN**	**GER**	**CAN**	**GER**	**CAN**	**GER**	**CAN**	**GER**	**CAN**
Res+Soc+Pgs+Opr	FR	FR	FR	FR	FR	FR	FR	FR	FR	FR

Figure 5.3: Sectorial peers of private and social analysis

It may be of some interest to use the above decomposition (5.1) to compare sectors across countries and investigate whether the causes of inefficiency differ. The following graphs (from 5.4 to 5.18) show, for each sector and each country, how social efficiency may be decomposed.[18]

As a second application, we exploit the OECD data set to prove the second part of proposition 4.2 by providing a counter example. We assume that a certain number of sectors, for various reasons (social, normative, etc.), may not be able to improve their efficiency, i.e. that rigidities affecting part of the economy prevent some sectors to change their observed techniques. We just let the 'rigid' sectors react to changes by adjusting their gross production levels and prices while we let the 'flexible' sectors choose their production techniques according to the private criterion, i.e. relying on current intermediate inputs prices. A suggestive interpretation of this situation is that a number of sectors are subject to sectorial authorities which impose them to improve their efficiency level, neglecting the interactions with other sectors.

[18] Further decompositions of the social efficiency measure are implementable. For example, the *distortion* term may be disentangled in a component accounting for the impact of price distortions on the optimal input mix and a component accounting for the impact on the minimum attainable cost. In addition, the social inefficiency of each sector may be decomposed so as to account for the amount of own inefficiency versus the amount of 'imported' inefficiency. It is beyond the scope of the present work to illustrate all possible decompositions. We want just to stress the illustrative power of this methodology (which rests, at the very end, on the reliability of the data set).

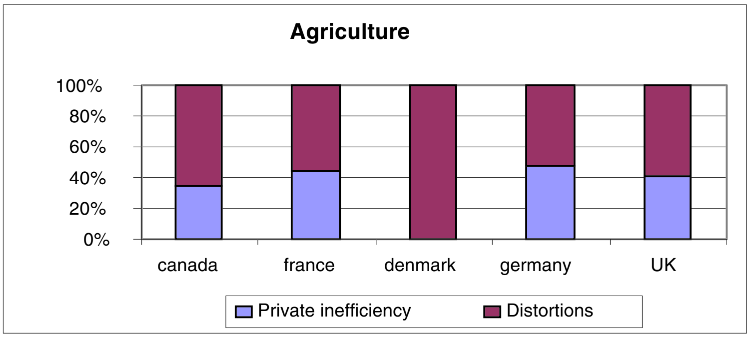

Figure 5.4:

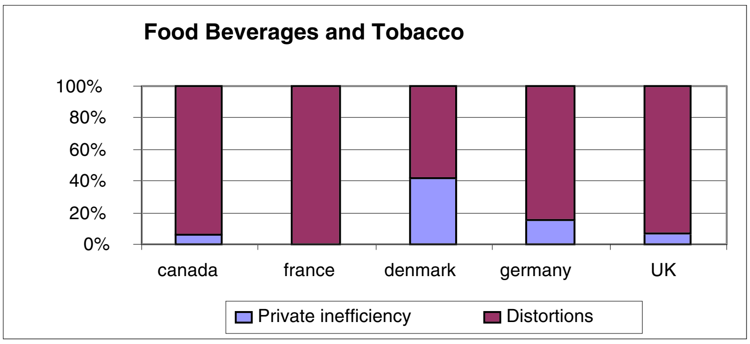

Figure 5.5:

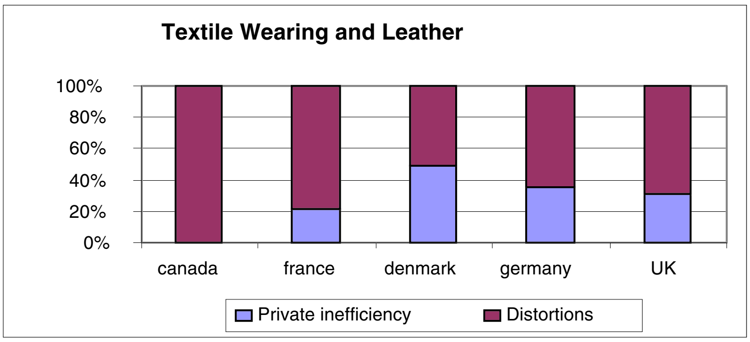

Figure 5.6:

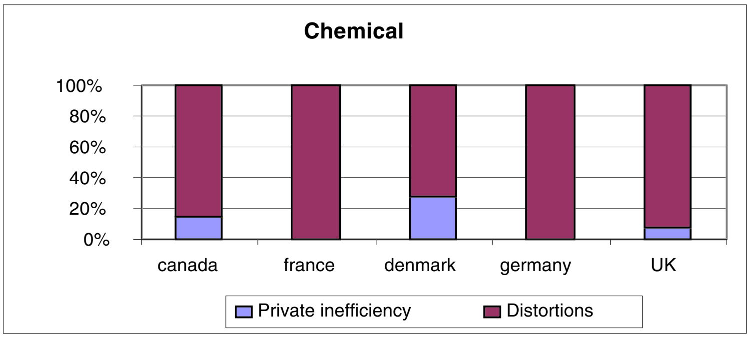

Figure 5.7:

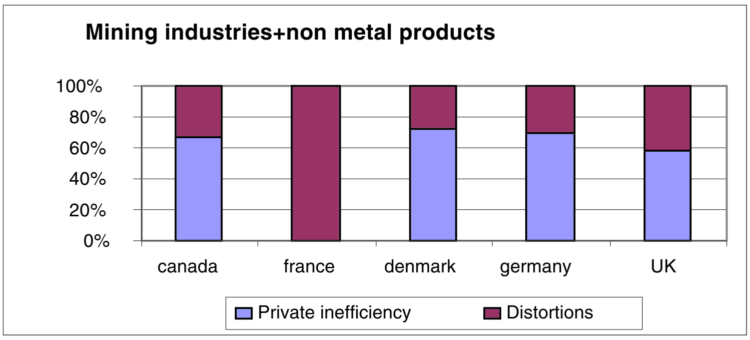

Figure 5.8:

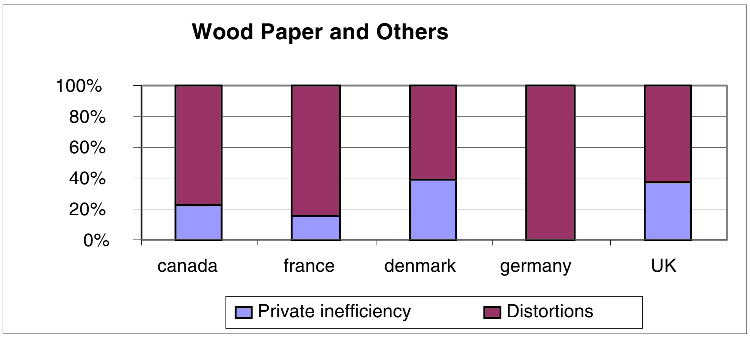

Figure 5.9:

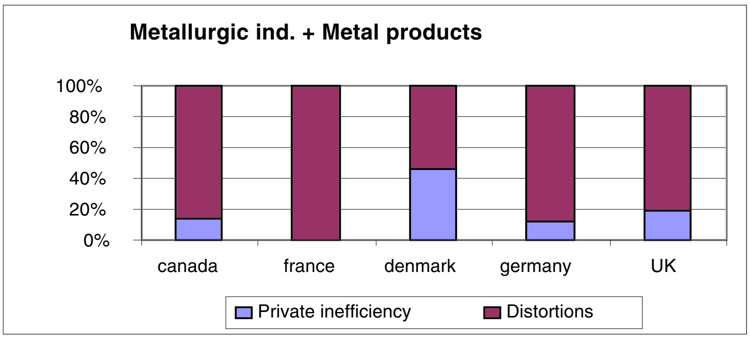

Figure 5.10:

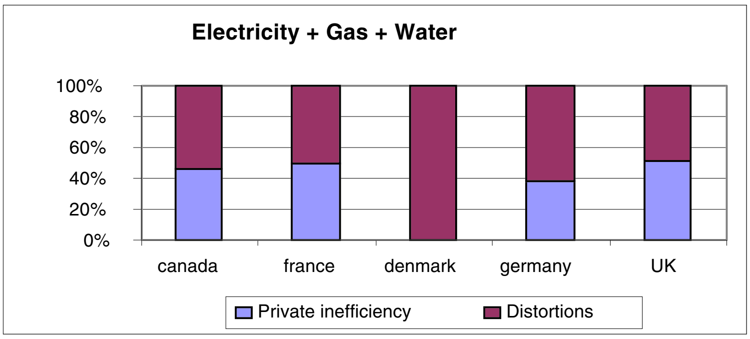

Figure 5.11:

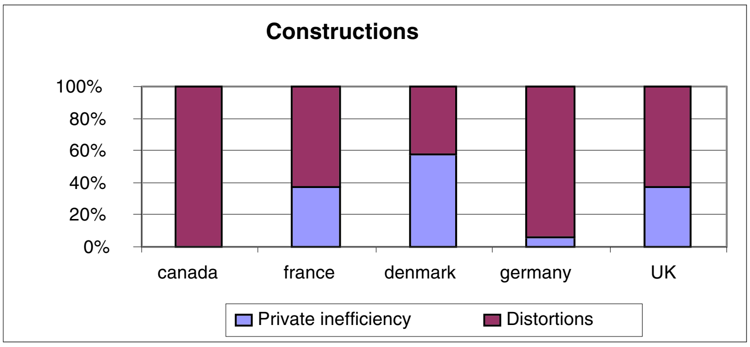

Figure 5.12:

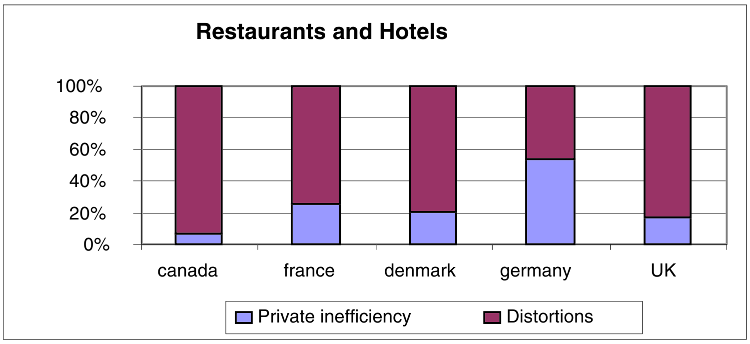

Figure 5.13:

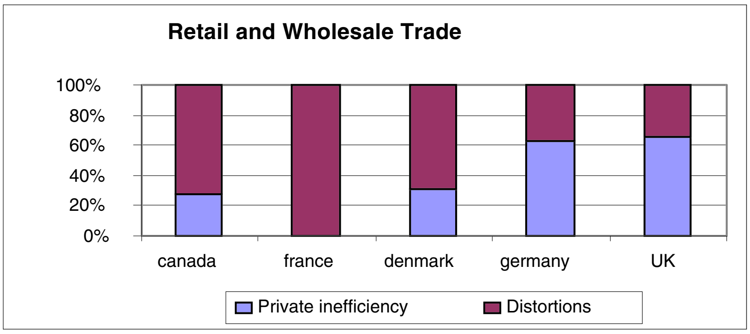

Figure 5.14:

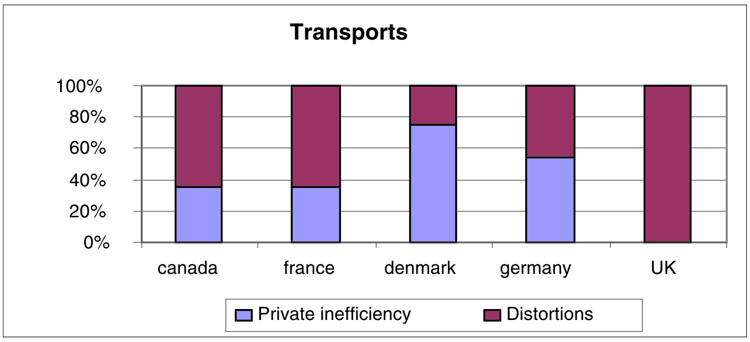

Figure 5.15:

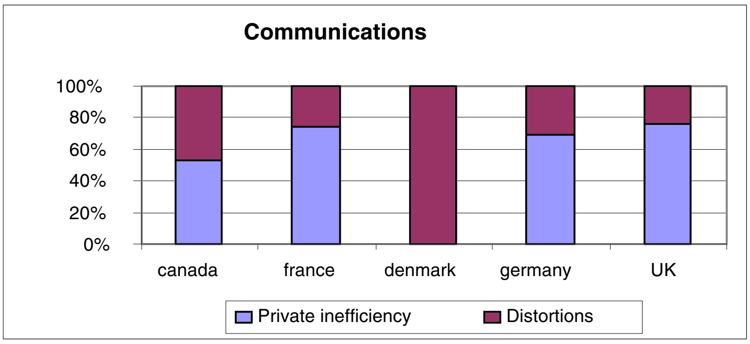

Figure 5.16:

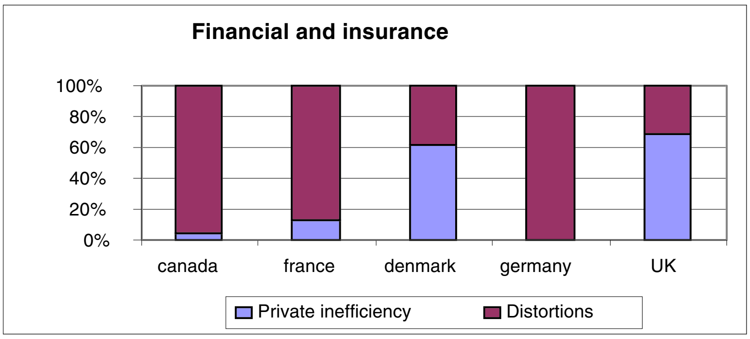

Figure 5.17:

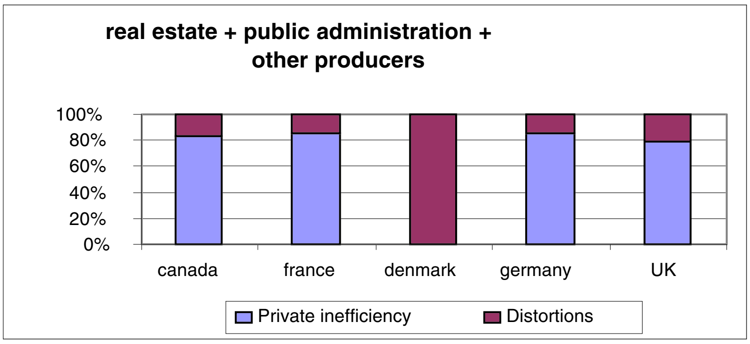

Figure 5.18:

We have already shown, in the previous section, (first part of proposition 4.2) that in this setup, if intermediate inputs prices reflect their current marginal costs of production, then the implementation of privately efficient techniques in the amendable sectors cannot lower the overall social efficiency. Conversely, the second part of proposition 4.2 states that if intermediate inputs prices embed market power, then the adoption of privately efficient production plans in a subset of sectors may decrease the level of (social) efficiency.

In order to show that this is true, we therefore let some sectors enjoy market power by including positive markups in their price-cost equations (see footnote 9).[19]

Then, we compute the total primary inputs costs of each economy assuming that one sector is able to choose the production technique that minimises its costs given the intermediate inputs prices, while the remaining sectors may only adjust their gross production level so as to still be able to satisfy the final demand. Finally, we compare such total primary inputs costs with the observed ones.[20]

[19] The mark-ups we use are consistent with the estimates by Martins, Scarpetta and Pilat (1996) and Martins and Scarpetta (1999) which provide estimates for 14 OECD countries relative to FOD, TEX, CHE, MID + MNM, BMI + MEQ, WOD + PAP + MOT. See details in table (5.4) in the appendix.

[20] We do the comparison both for the activity level satisfying the observed demand and for the unit activity level.

sector/countries	**France**	**Germany**	**UK**
FOD	**1,004076**	0,995342	0,998194
CHE	1	**1,002312**	**1,000539**
FNS	0,997828	**1,000044**	0,945347

Element (1,1) reports the ratio of primary inputs costs of the French economy (in the case that only the FOOD sector is able to modify its production technique according to the private criterion) to the observed primary inputs costs.
Element (2,1) does the same except for the fact that the unconstrained sector is the CHEMICAL one and so on.
In the case where (respectively) only sectors FOD and CHE were left free to adjust, we assumed a mark-up of 30% on the prices of the outputs of sectors AGR, FOD, TEX, CHE, MID + MNM.
In the case where FNS was left free to adjust, the mark-ups of Martins, Scarpetta and Pilat (1996) and Martins and Scarpetta (1999) were applied only on the food sector.
Also other price configurations give rise to similar results.

Figure 5.19: Ratio of total primary inputs cost of an economy where only a single sector (respectively FOD, CHE, FNS) is allowed to pursue private efficiency, to total observed primary inputs costs

sector/countries	**France**	**Germany**
CHE	**1,00429**	**1,002481**
FNS	0,998611	**1,000044**

Element (1,1) reports the ratio of primary inputs costs of the French economy (in the case that only the FOOD sector is able to modify its production technique according to the social criterion) to the observed primary inputs costs.

Figure 5.20: Ratio of total primary inputs cost of an economy where only a single sector (respectively CHE, FNS) is allowed to pursue social efficiency, to total observed primary inputs costs

Table (5.19) shows that under these conditions pursuing the private approach in a single sector may indeed be misleading, in the sense that it may even lead to an increase of total primary inputs cost in the economy. In fact, price distortions may induce a single sector to choose a production technique that, though allowing cost reductions at the sectorial level, may entail intermediate inputs requirements that raise the primary input absorption at the economy level.[21] *A partial implementation of privately efficient sectors may be made unfruitful by interindustry linkages.* The result needs to be considered carefully since it suggests that regulation in a single sector may be useless, if not detrimental, from the social standpoint.

The same conclusion applies in the case where social efficiency is pursued all over the economy while, due to rigidities, some sectors are not able to adjust quickly. As table (5.20) shows, the total primary inputs costs of the resulting economy may be larger than the total primary inputs costs of the observed economy.

Of course further simulations and estimations become necessary on a wider data set. One should also recall that the result rests upon a rigidity assumption.

6. Concluding remarks

This paper focuses on the role of interindustry relationships in the selection of socially efficient techniques in productive sectors. It argues that the current practice may provide misleading results because it rests upon the implicit assumptions that either each sector is isolated from the rest of the economy or that inefficiencies are not transmitted from sector to sector. Such an approach is followed, for example, in the *OECD Report on regulatory reform* (1997) that evaluates the impact of regulatory reforms in different countries. The same approach is followed by the price-cap ($RPI - X$) regulation, which focuses just on one sector and sets the X factor neglecting interindustry linkages (Armstrong and Cowan (1994)).

This paper argues that linkages across sectors need to be taken into account. This makes a distinction arise between social and private standpoints in the selection of efficient activities at the sector level (and, consequently, in the estimation of sectorial (in)efficiencies).

The distinction between the two standpoints stems from the intersectorial linkages which spread existing inefficiencies *via* intermediate inputs prices. A private approach to sectorial efficiency does not get rid of such distortions because

[21] Indirect evidence of this mechanism may be found in the OECD (1999) which states that 'comprehensive regulatory reform have produced results more quickly than piece-meals approaches' (p.4).

it usually takes market prices as given. The paper suggests that a social approach, conversely, should eliminate distortions by recurring to intermediate inputs prices which reflect the *minimum* marginal cost of production.

To this aim it proposes a consistent operational criterion for the selection of social efficient activities. By consistent we mean that it makes social and private standpoints coincide in a perfectly competitive world, and it allows a quantitative assessment of the differences between the two perspectives, whenever they arise.

An empirical analysis performed on a set of OECD interindustry data shows that the difference between the two standpoints is empirically relevant both in terms of the amount of inefficiency not captured by the private approach and in terms of 'wrong' selection of activities. More precisely, in most cases the social inefficiency of a given sector is largely due to inefficiencies imported from the economic system *via* distortions of intermediate inputs prices.

Because of these real world imperfections, the private approach may lead to the selection of socially inefficient techniques and therefore policy implications relevant to sectorial regulators or policy makers may arise. Two points are worth emphasizing. The first one concerns the identification of sectorial benchmarks. In order to be socially relevant, such benchmarks should be selected on the basis of intermediate inputs (shadow) prices reflecting their *minimum* marginal cost of production, as derived by the above criterion, based on a system approach. The current practice, however, may provide misleading results because it refers either to prices reflecting *observed* marginal costs or to observed market prices.

The second issue concerns the conditions under which a sectorial private approach may not only fail to achieve social efficiency but may even lower the current level of social efficiency. We first show that any approach to sectorial efficiency resting upon intermediate inputs prices reflecting their *observed* marginal costs of production improves (does not decrease) the current (social) efficiency level. Then, we show that, on the contrary, if prices embed some degree of market power, the implementation of privately efficient techniques in some sectors may even decrease the level of social efficiency. In such a case, therefore, the prescriptions of sectorial regulators may be detrimental to the system as a whole.

A *caveat* is in order. Due to the limitations of the OECD data set which, though useful, still lacks of relevant informations, the quantitative results of the empirical analysis have to be taken with caution. Further estimations on richer data sets, both in term of countries, sectors and prices, are needed. Further research may also address the issue of social versus private efficiency in a dynamic framework.

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A. Appendix

A.1. The data set[22]

The data set was extracted from the *OECD Input-Output Database*, which contains a number of comparable Input-Output tables from 1970 to 1990, both at constant and current prices, for ten OECD countries[23] disaggregated in 35 sectors. Primary inputs, capital and labour, were drawn from *ISDB 1997 - International Sectorial Database 1997* (whose level of disaggregation is lower, 31 sectors). The comparability of the tables is due to the *International Standard Industrial Classification* (ISIC) revision 2.

Data homogeneity was not always ensured, due both to discrepancies between national classification systems and the ISIC and to the different level of disaggregation of the transaction matrices and primary inputs matrices. For these reasons, sectors had to be aggregated from 35 to 15.[24] Moreover, five countries

[22] The dataset was elaborated by Maria Grazia Romano.

[23] Australia, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, United Kingdom and United States.

[24] The sectors are the followings:

1. AGR: agriculture
2. FOD: food, beverages and tobacco
3. TEX: textile, wearing and leather
4. CHE: industrial chemicals, rubber and plastic products
5. MID + MNM: mining and extractive industries + non metal products (excluding oil and coal products).
6. BMI + MEQ: metallurgic industries + metal products, machinery and equipment
7. WOD + PAP + MOT: wood products + paper products + other manufacturing
8. EGW: electricity, gas and water

had to be dropped from the sample.[25]

The analysis was performed on 1990 tables evaluated at constant prices.[26] The transaction matrices, expressed in national currencies, were converted in US$ using the following (GDP) PPP provided by the OECD:

GDP PPP

	1984	1985	1986	1990
Canada	-	-	1.280	1.303
Denmark	-	9.249	-	9.393
France	-	6.605	-	6.614
Germany	-	-	2.2	2.088
UK	0.536	-	-	0.6023

International Sectoral Database 1995 and 1997

The gross fixed capital stock, i.e. the total value of capital goods in a country, was also expressed in national currency. Capital stock values were converted in US$, using the gross fixed capital stock PPP, provided by the OECD:

GFC PPP

	1984	1985	1986	1990
Canada	1.318	1.308	1.296	1.266
Denmark	9.878	10.237	10.219	10.423
France	7.420	7.630	7.673	7.602
Germany	2.552	2.523	2.534	2.507
UK	0.7	0.728	0.739	0.845

OECD Statistics

9. CST: constructions
10. RWH: retail and wholesale trade
11. HOT: restaurants and hotels
12. TAS: transports
13. COM: communications
14. FNS: financial and insurance
15. RES + SOC + PGS + OPR: real estate + public goods + public administration + other producers.

[25] Italy and Holland were dropped because the 1990 tables were not available. Australia and USA were eliminated because capital stock data were not sufficiently disaggregated. Japan was not included because the capital stock did not comprise public investments. Canada, Denmark, France, Germany, and United Kingdom survived.

[26] Due to data availability problems the base years differ slightly across countries. The base year is 1984 for the UK, 1985 for Denmark and France and 1986 for Canada and Germany.

The rental price of capital was obtained as the ratio of the value of the (1990) capital stock at current prices to the value of the capital stock at constant prices, using for each country the appropriate base.

Total employment was defined as the total number of people (resident and non resident) contributing to the domestic production. Wages were obtained, for each sector, as the ratio of the wage bill, including social contributions, to total employment and converted in US$ using the GDP PPP.

The final demand was computed residually as the difference between gross production and intermediate inputs requirement.[27]

A.2. Table of OECD mark-ups estimates

sector/countries	**canada**	**france**	**denmark**	**germany**	**UK**
FOD	1,19	1,10	1,97	1,32	1,43
TEX	1,12	1,10	1,12	1,11	1,04
CHE	1,21	1,20	1,12	1,11	1,06
MID + MNM	1,34	1,30	1,25	1,16	1,07
BMI + MEQ	1,13	1,09	1,16	1,15	1,07
WOD + PAP + MOT	1,23	1,15	1,15	1,21	1,10

OECD estimates (Martins, Scarpetta and Pilat (1996) and Martins and Scarpetta (1999))

[27] Final demand was set equal to zero whenever negative (this may happen whenever the transaction matrix includes imports).