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Firm efficiency, industry performance and the economy: three-way decomposition with an application to Andalusia

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Abstract An economy may perform better because the firms become more efficient, the industries are better organized, or the allocation between industries is improved. In this paper we extend the literature on the measurement of industry efficiency (a decomposition in firm contributions and an organizational effect) to a third level, namely that of the economy. The huge task of interrelating the performance of an economy to industrial firm data is accomplished for Andalusia.

Keywords Input–output · Industrial organization · Comparative advantage · Allocative efficiency · Efficiency decomposition

JEL Classification L10 · D24 · O47

1 Introduction

Inefficiencies abound at the micro, meso and macro levels of the economy. Firms do not apply best-practices; industries may be organized suboptimally—with too many or too few firms—and the resources of the economy may be misallocated between industries. These concerns are the subject of the theory of the firm, industrial organization, and macro-economics, but are rarely connected. There are two reasons of this shortcoming. First, in the theoretical literature the focus of efficiency analysis is on the aggregation issue. Two levels are distinguished and there are more gains to be made than at the lower level: gains to trade in a system of regions or gains to reorganization in an industry. In this paper we extend the analysis to more levels. Second, modern economies comprise many industries and very many firms and it is a daunting task to express their performance in terms of the micro data. This paper makes a first attempt.

In the next section, we review a measure for the industrial organization efficiency. In Sect. 3, we propose an inclusion of the industrial specialization efficiency in the economy. In Sect. 4, the economy-wide efficiency is analyzed and decomposed. An application is presented in Sect. 5. The paper ends with some conclusions. Three appendices with a demonstration and data details and procedures are provided, along with a supplementary spreadsheet file containing detailed results.

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2 Review of organization efficiency

Following ten Raa (2011) the organization efficiency of an industry is analyzed by determining the output gain attainable from a reallocation of resources between the firms. We maintain ten Raa's implicit assumption that not only inputs but also outputs must have fixed proportions at the level of the firm, but not at the level of the industry. Industries produce their own products (primary outputs) and the products of other industries (secondary outputs). In the organization efficiency calculation we expand the own or primary output of an industry without requiring that secondary output increases at the same rate. This more flexible approach admits potential efficiency gains within industries which would be missed if ten Raa's (2011) output proportionality were maintained at the industry level. This flexibility at the industry level is consistent with the assumption of fixed proportions at the firm level, as is well understood ever since Houthakker (1956).

Denote the input and output vectors of firm i in industry k by x_{ik} and y_{ik}, $i \in I_k; k \in K$, where I_k is the set of the firms of the industry k and K is the set of the industries in the economy. e is a unitary vector of suitable dimension. The firm efficiency, ε_{ik}, is the solution to the following linear program:

$$\max_{\varepsilon_{ik},\lambda_{jk}\geq 0} e^{\mathrm{T}} y_{ik}/\varepsilon_{ik} : \sum_{j\in I_k} \lambda_{jk} x_{jk} \leq x_{ik}, \sum_{j\in I_k} \lambda_{jk} y_{jk} \geq y_{ik}/\varepsilon_{ik} \quad (1)$$

Expression (1) is a linear program in efficiency variable $1/\varepsilon_{ik}$ and allocation variables λ_{ik}. It includes a multiplicative constant in the objective function that will merely normalize the price variables in the dual program. Because a feasible solution to (1) is a reproduction of firm ik (by putting $\lambda_{ik} = 1$ and all other weights 0) the efficiency score ranges between 0 and 1. This is a data envelopment analysis (DEA) model with Constant Returns to Scale and Output orientation (DEA CRS-O).[1]

The dual program associated with (1) is:

$$\min_{p_{ik},w_{ik}\geq 0} w_{ik} x_{ik} : p_{ik} y_{jk} \leq w_{ik} x_{jk}, p_{ik} y_{ik} = e^{\mathrm{T}} y_{ik}, \quad j \in I_k, k \in K \quad (2)$$

where dual variables w_{ik} and p_{ik} are the shadow prices of the constraints of (1).

The efficiency of industry k, ε_k, is the solution to the next program:

$$\max_{\lambda_{jk}\geq 0,\varepsilon_k} e^{\mathrm{T}} \sum_{i\in I_k} y_{ik} \Big/ \varepsilon_k : \sum_{j\in I_k} \lambda_{jk} x_{jk} \leq \sum_{i\in I_k} x_{ik}, \sum_{j\in I_k} \lambda_{jk} \breve{y}_{jk} \geq \sum_{i\in I_k} \breve{y}_{ik}, \sum_{j\in I_k} \lambda_{jk} \hat{y}_{jk} \geq \sum_{i\in I_k} \hat{y}_{ik} \Big/ \varepsilon_k \quad (3)$$

where ε_k is again a number between 0 and 1, because a feasible solution is a reproduction of all firms in the industry. Superscript ^ denotes the primary output of industry k. Superscript ˘ denote the secondary outputs.[2] This notation will also be used for their prices. The idea is to reallocate the industry inputs, as to maximize k-specific output, inflating it by the expansion factor $1/\varepsilon_k$. Non-specific aggregate output, $\sum_{i\in I_k} \breve{y}_{ik}$, may also be expanded, but not necessarily in the same proportion. Since it remains at least the same, our expansion model is radial respect to the primary industry output, but non-radial respect to the rest of them. Li and Cheng (2007) call ε_k the structural efficiency of industry k when all outputs are expanded. They observe that a source of structural inefficiency is that individual production units may have suboptimal output mixes. Their individual production units are the Chinese provinces. We accommodate this freedom to change the output mix at the level of industry.

The basic idea in (3) is that the demand for products is fulfilled by the industries producing them as primary outputs and secondary outputs are produced as by-products, i.e. negative inputs; using idle resources. The primary outputs of industries are maximized, but not the secondary ones. It is a more flexible approach than ten Raa (2011) because the feasible set of Eq. (3) is larger, as demonstrated in "Appendix 1". The distinction between primary and secondary outputs and the focus on the former in assessing efficiency facilitates industries to focus on their comparative advantages.

[1] Details and complete DEA descriptions may be found in specific books such as Charnes et al. (1995) or Cooper et al (2000). We included constant $e^{\mathrm{T}} y_{ik}$ (which is total production of firm i of industry k, $^{\mathrm{T}}$is transposition) in the objective function; this monotonic transformation will prove useful for the price normalization.

[2] In national accounts statistics, firms are classified within industries following national or international classifications (NAICS in US, Canada and Mexico; NACE in the EU; ISIC in the UN) according to its primary output. However, firms usually produce also other commodities than its primary output (secondary ones) taking advantage of idle resources, i.e. a milk producing farm, whose primary output is producing milk for a diary products firms can also make home-made cheese to sell in a small shop and even provide rural tourism services with idle spaces and labor-force. Formally $\hat{y}_{jk}$ is the kth component of vector y and $\breve{y}_{jk}$ is the vector comprising all other components. Industry and commodity classifications usually match at the most common aggregation levels. i.e. NACE (Nomenclature of Activities of the European Union) matches CPA (Classification of Products by Activity) up to two digits level (breakdown in 89 industries/products): NACE: 01 Crop and animal production, hunting and related service activities CPA: 01 products of agriculture, hunting and related services. Then, the primary product of industry k is the product k. The difference among outputs made in (3) is conceptually different from that made by Lozano and Villa (2004) in their 'hybrid' centrally planned DEA models. In the present paper, the difference is made on the basis of the consideration of specific industrial output. On the other hand, the difference in Lozano and Villa (2004) among inputs in output-oriented models is based whether on being centrally planned or not. At first, one could think that both approaches are some how related, since we 'plan' to expand only the specific industrial output. However, it is to be highlighted that we include the difference among primary and secondary outputs on the oriented side of the model, this is, the output side, while these authors differentiate between both types of inputs (not outputs) on output oriented models and vice versa.

The dual program of (3) is:

$$\begin{aligned} &\min_{p_k, w_k \geq 0} w_k \sum_{i \in I_k} x_{ik} - \breve{p}_k \sum_{i \in I_k} \breve{y}_{ik} : \\ &p_k y_{jk} \leq w_k x_{jk}, \hat{p}_k \sum_{i \in I_k} \hat{y}_{ik} = e^{\mathrm{T}} \sum_{i \in I_k} y_{ik}, \quad j \in I_K \end{aligned} \tag{4}$$

where the dual variables w_k and p_k are the shadow prices of the constraints of (3).

ten Raa (2011) defined industrial organization efficiency of the industry k, ε_k^o as the gap between the efficiency of the industry, ε_k, and the weighed harmonic average of the efficiencies of the firms in the industry k, H_k:[3]

$$\varepsilon_k^o \cdot H_k = \varepsilon_k; \quad \varepsilon_k^o \bigg/ \sum_{i \in I_k} \frac{s_{ik}}{\varepsilon_{ik}} = \varepsilon_k$$

Consequently:

$$\varepsilon_k^o = \varepsilon_k \cdot \sum_{i \in I_k} \frac{s_{ik}}{\varepsilon_{ik}} \tag{5}$$

where ε_k is the ensemble efficiency determined by program (3), ε_{ik} are the efficiency scores of each firm determined by the set of programs (1) and s_{ik} are the revenue shares of each observed firm evaluated at the prices determined by dual program (4). These prices may be multiple, with possibly multiple market shares, but this multiplicity does not affect the values of the firm efficiency scores and the industry efficiency score, which are defined independent of prices. Even the condition for full industrial organization efficiency (namely equality between firm shadow prices and the industry shadow prices) holds under shadow price multiplicity; see the Remark following Proposition 2 in ten Raa (2011).

3 Industrial specialization efficiency

ten Raa and Mohnen (2002, 2008) analyze the reallocation of factors between industries to decompose Total Productivity Growth. ten Raa and Mohnen (2008) showed the interest of further decompose efficiency so as to consider the contribution of firms to it. The details are shown in the next section. With regard to the interpretation of efficiency measures, Shestalova (2002) further stated that the difference between augmented IOA (input–output analysis) and DEA lies on the interpretation of the frontier. The potential output is determined by the the best practices (DEA at industry level) or alternatively, by the reallocation of inefficiently allocated resources among industries (IOA in a multi-sectoral economy). To the best of our knowledge, the present paper is the first to simultaneously track the inefficiencies of the firms, the industries and the economy.

Industry efficiency is calculated with model (3) instead of a DEA-O CRS model. Then, we will work at the level of sectors $(k \in K)$, by pooling the vector of inputs and outputs within the firms of each industry k. The efficiency of the economy, ε, is obtained by

$$\begin{aligned} &\max_{\lambda_h \geq 0, \varepsilon} e^{\mathrm{T}} \sum_{k \in K} \sum_{i \in I_k} y_{ik} \bigg/ \varepsilon : \sum_{h \in K} \sum_{j \in I_h} \lambda_{jh} x_{jh} \leq \sum_{k \in K} \sum_{i \in I_h} x_{ik}, \\ &\sum_{h \in K} \sum_{j \in I_h} \lambda_{hj} y_{jh} \geq \sum_{k \in K} \sum_{i \in I_h} y_{ik} \bigg/ \varepsilon \end{aligned} \tag{6}$$

The dual program of (6), which variables w and p are the shadow prices of the constraints of the primal program, is:

$$\begin{aligned} &\min_{p, w \geq 0} w \sum_{k \in K} \sum_{i \in I_k} x_{ik} : p y_{jh} \leq w x_{jh}, p \sum_{h \in K} \sum_{j \in I_k} y_{jh} \\ &\qquad = e^{\mathrm{T}} \sum_{h \in K} \sum_{j \in I_h} y_{jh}, \\ &j \in I_k, h \in K \end{aligned} \tag{7}$$

The idea of (6, 7) is to compute the efficiency when the maximum output is reached letting the reallocation of inputs among industries, not only within industry. This estimates the efficiency of all the firms of all the industries (the whole economy) by comparing observed output with the maximum output reachable if there are no barriers to the flow of inputs across firms and industries. Such maximum is the output that could be produced by the most efficient firms using the resources of non-efficient firms, i.e.: "how much textile could be produced using the economic resources devoted to agriculture inputs" instead of "how much textile could be produced using the physical inputs of agriculture" or "how much textile could be produced with the agriculture best-practice technique", which is impossible.

It is to be highlighted that in Eqs. (6, 7), the benchmarks are the best practices (firms) of the whole economy: The intensities in Eq. (6), λ_{jh}, are per firm and there is an activity constraint for each firm in the second set of constraints of Eq. (7). Intensities and activity constraints by industries would account for the best 'industry-average' practices, instead of the absolute best practices of the economy, not drawing the real production possibility frontier, but an average observed production. It is the same difference highlighted by ten Raa (2007), when discussing the difference between traditionally computed IO (input–output) technical coefficients and technical coefficients obtained from best practices.

[3] In the averaging procedure described in (5), the weighted harmonic mean is used because it is the most suitable procedure for averaging productivities or performances, Casas Sánchez and Santos Peñas (1996, pp. 78–81). Indeed, according to Proposition 1 of ten Raa (2011) the harmonic mean of disaggregated efficiencies is an upper bound for aggregated efficiency.

Analogous to (5), industrial specialization efficiency, ε^s, is:

$$\varepsilon^s = \varepsilon \sum_{k \in K} \frac{s_k}{\varepsilon_k} \tag{8}$$

where ε is the ensemble efficiency (whole economy efficiency) determined by program (6), ε_k are the efficiency scores of each industry determined by the set of programs (3) and $s_k$are the revenue shares of each industry evaluated at the prices determined by dual program (7). The prices underlying these market shares may differ between industries and these differences signal industrial specialization inefficiency according to Proposition 2 of ten Raa (2011).

This ε^s accounts for, somehow, a matter of opportunity cost of the re-specialization of the output mix of the economy: the opportunity cost of producing a suboptimal output mix instead of the optimal one; this is, the cost in efficiency losses because of the wasting inputs in the production of inefficient commodities instead of in the most efficient ones (re-specialization of the output mix of the economy). This reflects the cost of the barriers to the mobility of inputs across industries: Some inputs are easy to mobilize (raw materials) because for a next season, a company can just stop buying it. Others may need training (labor force) or adaptation (capital investments). It may be impossible to take advantage of some of them and the only choice may be to wait till its depreciation (capital) or retirement (labor force).

4 Efficiency of the economy: three way decomposition

We are ready to present a single measure for the economy efficiency. Standard DEA techniques require a reference set and, therefore, are not applicable. Our measure, ε, will be derived internally. We build the efficiency measurement from the lowest level (firm) to the highest one (the whole economy) by a nesting decomposition of different efficiency measurements to isolate the effects at each level. Substituting (5) in (8) and reordering:

$$\varepsilon = \frac{\varepsilon^s}{\sum_{k \in K} \frac{\frac{s_k}{\varepsilon_k^o}}{\sum_{i \in I_k} s_{ik}/\varepsilon_{ik}}} \tag{9}$$

where ε^s is the industrial specialization efficiency calculated by (8), ε_k^o is the Organizational Efficiency of industry k, determined by (5), ε_{ik} are the efficiency scores of each firm determined by the set of programs (1), and s_{ik} and $s_k$are the revenue shares of each firm and each industry respectively, evaluated at the prices determined by dual programs (4) and (7).

At least theoretically the decomposition can be extended with an international/interregional level, bringing in the principle of comparative advantage, but this step requires comparable micro-data at an international level.

5 Application to the Andalusian economy

"Appendix 2" provides details about the database and computation and "Appendix 3" shows the classification of industries/commodities. Table 1 summarizes the results of Eqs. 1, 3 and 5: k is the industry code, ε_k is the industry k efficiency, ε_k^o is the organization efficiency of industry k and H_k is the firm's efficiency weighed harmonic average of firms of industry k. $\#_k$ is the number of firms within industry k.

The industries whose firms are technically inefficient could perform $1 - H_k$ percentage points better by copying best—industry—practices. The industries whose firms may work better, ranging from 60 to 12 % potential average improvement, are: Restaurants, bars and catering; Legal and Accounting services; Other services to firms; Wholesale trade; Advertising; Sale of motor vehicles and retail sale automotive fuel; Land Transport; Maintenance and repair of motor vehicles; Building completion; Architectural and engineering activities and related technical consultancy.

The industries whose organization is inefficient could perform H_k–ε_k percentage points better by exploiting economies or diseconomies of scope. Ranging from 79 to 36 % of potential improvement, the industries with the worst organization are: Architectural and engineering activities and related technical consultancy; Real estate activities; Retail trade; Wholesale trade; Other services to firms; Supporting and auxiliary transport activities; Sale of motor vehicles and retail sale automotive fuel; Restaurants, bars and catering; Land transport; and Renting of machinery and equipment. Most of them are typically composed by small-sized firms.

On the other hand, 29 industries[4] are fully efficient. Another 22 industries could improve as much as 10 % of their performance by a better industrial organization.

In order to improve the industrial organization in the industries with the worst organization (previously mentioned in the paragraph above) the resources suboptimally allocated to specialized firms may be better reallocated and merged with the resources of optimal firms. On the other hand, the resources suboptimally allocated to diversified firms would be better split and distributed among optimal firms. Suboptimality is signalled by the mismatch of firms'

[4] Note that 22 of them are industries with a single observation (see $\#_k$ in Table 1), which are efficient by definition, and consequently such industries are also efficient. See "Appendix 2" for further details.

Table 1 Industry efficiencies: industry, organizational, firms mean

k	ε_k	ε_k^o	H_k	$\#_k$	k	ε_k	ε_k^o	H_k	$\#_k$
01	1	1	1	1	44	0.88	0.90	0.98	101
02	1	1	1	1	45	1	1	1	5
03	1	1	1	1	46	1	1	1	1
04	1	1	1	1	47	1.00	1.00	1.00	39
05	1	1	1	1	48	0.97	0.97	1.00	85
06	1	1	1	1	49	0.80	0.84	0.96	1,574
07	1	1	1	8	50	0.57	0.66	0.87	1,610
08	1	1	1	2	51	0.44	0.52	0.85	1,468
09	0.81	0.81	1.00	135	52	0.68	0.78	0.86	946
10	0.92	0.92	1.00	167	53	0.16	0.21	0.75	5,933
11	1.00	1.00	1	28	54	0.31	0.31	0.98	8,887
12	0.99	0.99	1	41	55	0.69	0.75	0.93	673
13	0.99	0.99	1	43	56	0.00	0.00	0.40	2,399
14	1.00	1.00	1.00	42	57	0.46	0.54	0.85	1,995
15	1	1	1	4	58	1.00	1.00	1.00	19
16	1	1	1	5	59	0.53	0.55	0.97	966
17	0.80	0.81	0.99	559	60	0.97	0.98	1.00	417
18	0.89	0.89	1	82	61	1	1	1	1
19	1.00	1.00	1	22	62	1	1	1	1
20	0.92	0.92	1.00	113	63	0.75	0.80	0.94	332
21	0.72	0.75	0.96	200	64	0.28	0.28	1.00	808
22	0.90	0.91	0.99	117	65	0.59	0.62	0.95	480
23	0.81	0.82	0.98	254	66	0.57	0.62	0.92	292
24	0.97	0.97	1.00	53	67	0.92	0.93	0.99	65
25	0.90	0.91	0.99	202	68	0.21	0.39	0.55	1,390
26	1	1	1	3	69	0.09	0.10	0.88	794
27	1.00	1.00	1	44	70	0.51	0.66	0.77	199
28	0.99	0.99	1.00	68	71	0.81	0.82	0.98	146
29	0.92	0.92	1.00	122	72	0.58	0.63	0.93	336
30	0.89	0.90	0.99	341	73	0.08	0.14	0.60	901
31	0.88	0.88	1.00	117	74	1	1	1	1
32	0.92	0.92	0.99	183	75	1	1	1	1
33	1.00	1.00	1.00	37	76	1	1	1	1
34	0.75	0.78	0.96	695	77	1	1	1	1
35	0.88	0.88	1.00	268	78	0.92	0.92	1.00	155
36	1.00	1.00	1	13	79	0.98	0.98	1	72
37	0.89	0.89	0.99	86	80	0.85	0.85	1.00	101
38	1	1	1	23	81	0.80	0.80	1.00	201
39	0.98	0.98	1.00	59	82	0.98	0.98	1.00	44
40	0.99	0.99	1.00	60	83	0.86	0.87	0.98	231
41	0.79	0.79	1.00	89	84	0.68	0.69	0.99	571
42	1	1	1	21	85	0.92	0.93	0.99	272
43	0.78	0.82	0.95	445	86	1	1	1	1

ε_k: efficiency of the industry k, Eq. 3; ε_k^o: organization efficiency of the industry k, Eq. 5; $\#_\kappa$: # firms in industry k. H_k: mean efficiency of firms in industry k, Eq. 1. 1.00: rounded when reducing decimals but smaller than 1

Table 2 Economy efficiencies: economy, specialization and industrial mean

ε	ε^s	H	#
0.679254	0.895355	0.758642	86

ε: efficiency of the economy, Eq. 7; ε^s: specialization efficiency, Eq. 8. #: # of industries in the economy; H: mean efficiency of the industries in the economy, Eq. 3

marginal productivities (prices that solve Eq. 2) and the industrial marginal productivities (prices that solves Eq. 4).

The marginal productivities of inputs for the firms of each industry are expressed in the sheet W of the supplementary spreadsheet file, as results in Eq. (2). Analogously, the industries' marginal productivities, as results in Eq. (4), can be seen at the end of the same sheet W. The same structure applies in sheet P of the supplementary file.

The resources of the firms with marginal productivities lower than the correspondent industrial prices are over-allocated resources. They would be better reallocated to the firms with higher marginal productivities. This kind of information can be useful, for example, to identify candidates for merges.

Table 2 summarizes the results of Eqs. 3, 6 and 8: ε is the efficiency of the whole economy, ε^s is the specialization efficiency of the economy and H is the industries' efficiency weighed harmonic average. # is the number of industries. The overall inefficiency of the economy is 32 %. Formula (8) decomposes this figure in 10.5 % specialization inefficiency and 24 % industry inefficiency. (The figures do not add because of the nonlinearity in the formula.)

As far as the specialization of the economy is inefficient, then, it can be improved by changing the output mix. Formula (8) implies that if the specialization were optimal ($\hat{\varepsilon}^s = 1$), the hypothetical economy efficiency, $\hat{\varepsilon}$, would be equal to the average industry efficiency:

$$\hat{\varepsilon} = \frac{\hat{\varepsilon}^s}{\sum_{k\in K} \frac{s_k}{\varepsilon_k}} = \hat{\varepsilon}^s \cdot H = 1 \cdot 0.76 = 0.76$$

Thus, the economy could do better in around 8 percentage points ($\hat{\varepsilon} - \varepsilon = 0.76 - 0.68 \approx 0.08$), applying the 'best-practices in the economy' and consequently changing its output mix in order to improve the commodity specialization. By contrast, applying the 'industrial best-practices', as in Eqs. (3, 4), it would improve the efficiency of the industries by the reallocation resources to the best industrial organization of each industry, but without a change in the firms' specialization.

Suboptimality is signalled by the mismatch among the industrial's marginal productivities (prices that solve

Eq. 4) and the whole economy marginal productivities (prices that solve Eq. 7).

The capital and labor productivities sustaining the economy-wide efficiency (Eq. 7) are reported in Table 3. Analogously, the industrial marginal productivities (Eq. 4), can be seen in Table 4.

The industrial resources with marginal productivities lower than their economy counterpart are over-allocated resources. They would be better relocated to industries with higher marginal productivities. This kind of information can be useful, for example, to identify for which industries project-financing policies are more profitable in front of those industries where the capital is redundant (capital resources reallocation). Analogously, it signals where the allocation of human resources is more efficient (labour reallocation), identifying in which industries and what kind of the retraining policies would be suitable to help in the change of the output mix of the economy.

The industry in which the capital presents the highest marginal productivity is, by far, Architectural and engineering activities and related technical consultancy, followed by other service to firms; Manufacture of grain mill, starches and starch products; Real estate activities; and Insurance and pension funding. The fact that some of them are closely related to the building industry (architectural

Table 3 Economy marginal productivities of capital and labour (Eq. 7)

Capital	Labour
0.16	0.20

Table 4 Industrial marginal productivities of capital and labour (Eq. 4)

k	Capital	Labour	*k*	Capital	Labour	*k*	Capital	Labour
01	0.00	0.00	30	*1.26*	*0.62*	59	*1.30*	*66.27*
02	0.00	0.00	31	*1.80*	*0.65*	60	*1.53*	*31.81*
03	0.00	0.00	32	*1.73*	*0.58*	61	0.00	0.00
04	0.00	0.00	33	0.00	*0.32*	62	*12.89*	0.00
05	0.00	0.00	34	*4.09*	*0.55*	63	*3.45*	*28.87*
06	0.00	0.00	35	*0.70*	*0.64*	64	*14.62*	*313.66*
07	*3.35*	0.00	36	*4.07*	*0.21*	65	*1.43*	*39.45*
08	0.00	0.00	37	0.00	*1.76*	66	*0.64*	*29.54*
09	*3.11*	*0.53*	38	0.00	0.00	67	*1.78*	*31.10*
10	*0.45*	*0.46*	39	*5.30*	*0.41*	68	0.00	*155.86*
11	0.00	0.14	40	*0.17*	*0.39*	69	*169.85*	*55.06*
12	*1.23*	0.07	41	0.00	*0.69*	70	*2.67*	*34.44*
13	*0.76*	0.12	42	0.08	0.07	71	0.00	*22.25*
14	0.00	0.14	43	*0.94*	*0.49*	72	*2.84*	*17.04*
15	*19.95*	*0.72*	44	*2.53*	*0.68*	73	*40.99*	*109.25*
16	0.00	0.00	45	*4.98*	0.00	74	0.00	0.00
17	0.00	*0.43*	46	0.00	0.00	75	0.00	*37.00*
18	0.00	*0.20*	47	0.00	0.00	76	0.00	0.00
19	0.00	0.00	48	*0.62*	*0.31*	77	0.00	0.00
20	*2.41*	*0.36*	49	*0.46*	*29.79*	78	*2.19*	*31.78*
21	*1.40*	*0.44*	50	*3.00*	*25.83*	79	0.00	0.00
22	*4.57*	*0.49*	51	0.00	*0.95*	80	0.00	*10.02*
23	*0.34*	*0.70*	52	*2.88*	*20.08*	81	0.00	*20.18*
24	*1.66*	*0.94*	53	0.00	*4.88*	82	*8.95*	*7.29*
25	*1.22*	*0.35*	54	0.00	*0.45*	83	0.00	*12.33*
26	0.00	0.00	55	*0.69*	*22.28*	84	0.00	*148.63*
27	*0.54*	*0.52*	56	0.00	*529,167.01*	85	*1.62*	*13.37*
28	*0.33*	*0.36*	57	0.00	*128.44*	86	0.00	*4.65*
29	*2.72*	*0.94*	58	*4.78*	*6.95*			

Italics script: value higher than the correspondent of Table 3

Roman script: value lower than the correspondent of Table 3 activities and real estate) is logical, as far as the data correspond to the year 2000, the beginning of the real estate bubble, whose blast has had a large impact in Spain. However, none of them is exactly building, but just related activities. This implies that the main gains in real estate and related activities were not in the building industry but in the related activities. This shows a path for building companies in Andalusia after the real estate blast: related activities. Actually, it is what many of them have done: offshoring of activities related to building. Civil engineering has suffered the blast in a lesser extent. Then, the Spanish building corporations have disembarked in international projects using the architects and engineers of their headquarters and locally hiring bricklayers by their subsidiaries. Thus, they have re-orientated their production by increasing their 'exports' of Architectural and engineering activities and consultancy and by using their 'excess' of capital underused for building, by investing in other countries, then out of our accountancy.

Analogously, the industry in which labour is the most profitable is, by large, Restaurants, bars and catering; far followed by real estate activities; Legal and Accounting services; Other entertainment, cultural and sport activities; Land Transport; and Other services to firms. Some of them are very related to Tourism (Restaurants, bars and catering; Real estate activities; Other entertainment, cultural and sport activities and Land Transport), one of the main industries in Andalusia, which represents[5] during the reference year (2000) 13.1 % of regional GDP and 10.8 % of the employment. The main tourism-related industry (Hotels) is not included and it is the industry which has most largely suffered the crisis. This is because of two factors: a demand totally dependant on tourism and small chances to reorient its activity in the short term due to its large physical capital investments. On the other hand, the physical investments of Restaurants, bars and catering; Real estate activities; Other entertainment, cultural and sport activities and Land Transport are quite smaller and have a more diverse demand made not only by tourists but also by locals.

The industrial outputs with industry-specific prices lower than competitive prices (economy counterpart) are inefficient. Those industries would be better producing outputs with higher industrial prices. i.e.: The industry of water transport would do better producing more "other services to firms" instead of "forestry and related activities" (cells BW39334 vs. G39334 in the sheet P of the supplementary spreadsheet file). The industry of Other entertainment, cultural and sport activities would do better by producing (in this order) Manufacture and distribution of gas and gaseous fuels through mains; Hotels; camping sites and other provision of short-stay accommodation; Market Social services; Market education; Manufacture of prepared animal feeds; Production, processing and preserving of meat and meat products; Other manufacturing; Growing of vegetables and horticultural specialties; Real estate activities; Cinema, radio and television; and Advertising. However, it is probable that the production of these products is not separable since some of them can be secondary products of the main activity. A joint study of such targets suggests that this industry would do better in producing more educational farms and rural tourism services that involve many of the suggested targets (Hotels; camping sites and other provision of short-stay accommodation; Market Social services; Market education; Manufacture of prepared animal feeds; Production, processing and preserving of meat and meat products; Other manufacturing; Growing of vegetables and horticultural specialties; Real estate activities).

The industries that present a price for their specific output lower than the competitive economy counterpart, do produce no other output. This rule holds for any industry except for the industry of products of refining petroleum which would do better if they produce more real estate services than its main output (cells BN39302 vs. AB39302 in the sheet P of the supplementary spreadsheet file) or the industries of Manufacture of gas, distribution of gaseous fuels through mains; and Collection, purification and distribution of water. However, such commodities are produced by natural monopolies, which are, by definition, the furthest industries from the competitive equilibrium—which is the main assumption of this model. The results show that the most efficient commodities are trade (retail trade of manufactured products and wholesale trade of services), real estate activities, and other services to firms.

The signalling of trade suggests that the direct sale of manufacturers (retail shops in factories) and the wholesale trade of services are profitable. By contrast, the latter is usually devoted to retail trade to firms, instead of to the wholesale trade. Besides, the signalling of the real estate activities is logical, as far as the data are from the year 2000 (at the beginning of the real estate bubble). Finally, the positive signal of the services to firm is expectable in a developed economy where outsourcing is a main trend.

The fact that we have only a single observation for some industries (see "Appendix 2" for details) looks to be related to the fact that for such industries no change in the output mix is suggested.

6 Conclusion

An economy may perform better, in the sense of productivity growth, by technical progress or by efficiency

[5] Exceltur (2005).

change. The latter source of growth has been decomposed in industry and firm contributions, but the aggregation is known to be imperfect. The bias in the aggregation of the efficiencies of the firms and industries reflects the allocative inefficiency in an economy.

Efficiency gains could arise from three sources, namely firms, industrial organization and commodity specialization: Inefficient firms could replicate best-practices. At least two-thirds of the industries could improve their efficiency more than 10 percentage points by industrial reorganization. Finally, the economy could improve its performance 8 percentage points by a change in its output mix.

Inefficient firms may analyze their peers and redesign the production process reallocating the budget to the proper resources and demanding them similar results to those of their peers. The industries whose firms can improve the most are those with the lowest average efficiency: Restaurants, bars and catering; Legal and Accounting services; Other services to firms; Wholesale trade; Advertising; Sale of motor vehicles and retail sale automotive fuel; Land Transport; Maintenance and repair of motor vehicles; Building completion; Architectural and engineering activities and related technical consultancy. Anyhow, a detailed study firm by firm is more informative than the study of industrial averages.

The reallocation of the resources of each industry involves corporate finance to improve industrial organization and enhance economies of scope. The industries that can improve their organization the most are those with the lowest organization efficiency: Architectural and engineering activities and related technical consultancy; Real estate activities; Retail trade; Wholesale trade; Other service to firms; Supporting and auxiliary transport activities; Sale of motor vehicles and retail sale automotive fuel; Restaurants, bars and catering; Land transport; and Renting of machinery and equipment. The change in the output mix involves the reallocation of the resources along the whole economy (beyond industries distinction). For that, changes in the activity of the firms of suboptimal oriented industries are needed and resistances need to be overcome.

The results show that the production of trade (retail trade of manufactured products and wholesale trade of services), real estate activities, and other services to firms is more efficient. The use of capital is the most efficient in real estate while the use of labour is the most efficient in tourism.

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Appendix 1: Proof

We demonstrate that the feasible set of Eq. (3) is larger or equal than the feasible set of the industry model presented in ten Raa (2011). The latter is characterized by the pair of constraints $\sum_{j\in I_k}\lambda_{jk}x_{jk}\leq\sum_{i\in I_k}x_{ik}$, $\sum_{j\in I_k}\lambda_{jk}y_{jk}\geq\sum_{i\in I_k}y_{ik}/\varepsilon_k$. In Eq. (3) the first constraint is copied, as is the k-th component of the second constraint. The other components, $\sum_{j\in I_k}\lambda_{jk}\breve{y}_{jk}\geq\sum_{i\in I_k}\lambda_{ik}\breve{y}_{ik}\Big/\varepsilon_k$ are replaced by $\sum_{j\in I_k}\lambda_{jk}\breve{y}_{jk}\geq\sum_{i\in I_k}\lambda_{ik}\breve{y}_{ik}$. Because ε_k is an efficiency score between zero and one, this replacement is a relaxation.

Appendix 2: Data and computation details

The IEA (Instituto de Estadística de Andalucía—Regional Statistical Office of Andalusia) provided the cross-section inputs and outputs establishment data. These data were used for the elaboration of the Input–Output Andalusian Framework 2000—MIOAN00 (IEA 2006), which is the input–output table for Andalusia, based on the European System of Accounts (ESA-95) published by EUROSTAT (1996). IEA publishes two use tables, which differ by valuation. One is valued at purchasers' prices and the other at basic prices, which is the same as the former but excluding trade and transport margins and net commodity taxes (see Viet 1994, p. 28). Trade and transport margins needs simply be reallocated from the commodities where they are included, at purchasers' values, to the use matrix rows of trade and transport services. The make table is published exclusively at basic prices. The United Nations System of National Accounts (SNA) recommends basic values; production costs of good and services are measured before they are conveyed to the market for consumption so that the effects of tax and subsidy policies as well as of differences in types of economic transactions are isolated. Valuations are in basic prices. ten Raa and Rueda-Cantuche (2007) detail the procedure, including the assumed equality

Table 5 Industries not surveyed for MIOAN00

k	Industry
01	Growing of vegetables and horticultural specialties
02	Growing of vineyard and olive
03	Other agricultural products and services
04	Livestock and hunting
05	Forestry and related service activities
06	Fishing
46	Manufacture of electricity
61	Financial intermediation
62	Insurance and pension funding
74	Public administration and defence; compulsory social security
75	Non-market education
76	Market education
77	Non-market health and veterinary activities
86	Activities of households as employers of domestic staff

Source: IEA (2006)

of margins and net commodity taxes between establishments in a given industry, consuming a given commodity.

There is a single capital type and a single labour type. Data for each establishment is obtained from capital consumption and total equivalent employees figures in the IO dataset. The capital endowment and the total labour force are the sum across establishments of their capital consumption and total equivalent employees figures.

Sales and purchases were classified into 86 commodities, then 88 inputs (86 commodities and 2 factor inputs: capital and labour) and 86 outputs were considered for 39,272 observations: 39,258 obtained by IEA from specific surveys done to build MIOAN00 while the other 14 observations represent data of sectors which data are obtained by IEA from different statistical sources when building MIOAN00, instead of by specifically surveying establishments: The list of this latter group of sectors is presented in Table 5.

We do not claim that the data were measured without error. Particularly, basic prices building follow some usual assumptions. For a sensitivity analysis we refer to ten Raa (2005).

The results have been computed using a specifically designed and optimized GAMS v21.6 code that uses Cplex Solver. It has taken 10 h to run it on a laptop with a processor Pentium Centrino Duo 1.66 Ghz with 32-bits architecture and 2 Gb RAM.

Appendix 3: Industry/commodity classification

See Table 6.

Table 6 Industry classification in MIOAN00

k	Industry
01	Growing of vegetables and horticultural specialties
02	Growing of vineyard and olive
03	Other agricultural products and services
04	Livestock and hunting
05	Forestry and related service activities
06	Fishing
07	Energy products
08	Mining of metal ores
09	Mining of non metal ores and non energy ores
10	Production, processing and preserving of meat and meat products
11	Processing and preserving of fish and fish products
12	Processing and preserving of fruit and vegetables
13	Manufacture of vegetable and animal oils and fats
14	Manufacture of dairy products
15	Manufacture of grain mill, starches and starch products
16	Manufacture of prepared animal feeds
17	Manufacture of other food and tobacco products
18	Distilling, rectifying and blending of spirits; ethyl alcohol production
19	Manufacture of beer, soft drinks; production of mineral waters
20	Preparation and spinning of textile fibres; weaving of textiles
21	Manufacture of wearing apparel, dressing of fur
22	Dyeing of fur; manufacture of articles of fur
23	Manufacture of products of wood; cork (exc. Furniture)
24	Manufacture of paper and paper products
25	Products of publishing of books, forms and other publications
26	Manufacture of refined petroleum products
27	Manufacture of basic chemicals, inclusive agrichemicals
28	Manufacture of other chemical products n.e.c.
29	Manufacture of rubber and plastic materials
30	Manufacture of cement, lime and plaster
31	Manufacture of non-refractory clay and ceramic products
32	Stone and glass products
33	Metallurgy products
34	Manufacture of metal products
35	Manufacture of machinery and equipment
36	Manufacture of office, accounting and computing machinery
37	Manufacture other electrical equipment n.e.c.
38	Manufacture of electronic, tv, radio and communications equipment and apparatus
39	Manufacture of medical and surgical equipment and optics and precision equipment
40	Manufacture of motor vehicles, trailers and semi-trailers
41	Building and repairing of ships and boats
42	Manufacture of other transport equipment n.e.c.
43	Manufacture of furniture
44	Other manufacturing n.e.c.
45	Recycling products

Table 6 continued

k	Industry
46	Manufacture of electricity
47	Manufacture of gas; distribution of gaseous fuels through mains
48	Collection, purification and distribution of water
49	Building and civil engineering
50	Building completion
51	Sale of motor vehicles and retail sale automotive fuel
52	Maintenance and repair of motor vehicles
53	Wholesale trade
54	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods
55	Hotels; camping sites and other provision of short-stay accommodation
56	Restaurants, bars and catering
57	Transport via railways and other land transport, inclusive pipeline
58	Sea and coastal water and air transport
59	Supporting and auxiliary transport activities
60	Post and telecommunications
61	Financial intermediation
62	Insurance and pension funding
63	Activities auxiliary to financial intermediation
64	Real estate activities
65	Renting of machinery and equipment
66	Hardware, software consultancy and supply, data processing and data base activities
67	Research and development services
68	Legal and accounting services
69	Architectural and engineering activities and related technical consultancy
70	Advertising
71	Private security and investigation services
72	Manufacture cleaning activities
73	Other service to firms n.e.c.
74	Public administration and defence; compulsory social security
75	Non-market education
76	Market education
77	Non-market health and veterinary activities
78	Market health and veterinary activities
79	Non-market social services
80	Market social services
81	Sewage and refuse disposal
82	Activities of organizations
83	Cinema, radio and television
84	Other entertainment, cultural and sport activities n.e.c.
85	Other personal services
86	Activities of households as employers of domestic staff

Source: IEA (2006)

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