The distinction of direct and indirect inputs in the Input-Output subsystem approach

Alessandro Sarra[1], Marialisa Mazzocchitti[2], Donatella Furia[3]

Author affiliations

[1] [Corresponding Author] Dipartimento di Economia, "G. d'Annunzio" University of Chieti and Pescara, Pescara, Italy

[2] Dipartimento di Economia, "G. d'Annunzio" University of Chieti and Pescara, Pescara, Italy

[3] Dipartimento di Scienze Filosofiche, Pedagogiche ed Economico-Quantitative, "G. d'Annunzio" University of Chieti and Pescara, Pescara, Italy

Author contact details

[1] [Corresponding Author] Viale Pindaro 42 – 65127 – Pescara, Italy; alessandro.sarra@unich.it

[2] Viale Pindaro 42 – 65127 – Pescara, Italy; marialisa.mazzocchitti@unich.it

[3] Viale Pindaro 42 – 65127 – Pescara, Italy; donatella.furia@unich.it

Confirmation of corresponding author

As Corresponding Author, I Alessandro Sarra, regarding the paper submitted under the title 'The distinction of direct and indirect inputs in the Input-Output subsystem approach', declare that the manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

I can confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed.

I further confirm that the order of authors listed in the manuscript has been approved by all of us.

I understand that the Corresponding Author is the sole contact for the Editorial process and is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs.

Best regards,

Alessandro Sarra

Abstract

Input-Output analysis, and the subsystem approach in particular, have been widely used in the literature to assess the nature and process of structural change of national economies, with particular reference to deindustrialization and tertiarization processes, as well as to the evolution of the level of centrality of manufacturing in GDP growth. Our paper suggests a methodology to separate, within the subsystems, direct inputs from indirect inputs, which depend on the Input-Output production function and the general organization of the economic system respectively. We provide an example of the application of such methodology to the manufacturing subsystems in Germany and Italy over the period 2000-2014.

Keywords

input-output analysis; subsystem approach; structural change; direct and indirect inputs

JEL codes

C67; D57; P51

1. Introduction

In recent years, a number of studies investigated the deindustrialization processes of the major European economies after the 2008 crisis. Their aim was to discuss the controversial structural effects of the horizontal approach of the European Union to industrial policy, and the emergence of a 'manufacturing imperative' (Chang 2006; Rodrik 2011) which required more selective strategies at the sectoral and geographical levels. These strategies should be based on the specific features of the processes of structural change in the Member States' economies, which evolved in very different ways. In particular, diverging trends affected the so-called German-Centred Core and the countries of the Southern Periphery, among which Italy experienced a substantial weakening of its industrial base.

Some of these studies make use of Input-Output analysis (Montresor and Vittucci Marzetti 2011; Sarra et al. 2018). Building on the subsystem approach (Momigliano and Siniscalco 1986, 1982; Pasinetti 1973), they measure in terms of employment/hours worked the portion of the economic activity triggered by the need to meet the final demand for manufactured goods (the amount of employment/hours worked which is directly or indirectly used to that purpose in the whole economy), under the theoretical hypothesis of perfect vertical integration (the production of final goods is supposed to be carried out by a virtual system which uses a given amount of fixed assets and buys only labour from the outside).

There are two main questions that are addressed by this literature: if the share of employment/hours worked for the production of final manufactured goods decreases over time (deindustrialization); if and to what extent the share of employment/hours worked in intermediate services over the total hours worked in the manufacturing subsystem increases over time (growing integration between industry and services, according to the typical language of I-O analysis, is normally considered a sign of modernity of the national industrial structure).

What this literature has not hitherto attempted is to separate the value of direct and indirect inputs within the subsystems, and in particular within the manufacturing subsystem. The answer to both the questions above can be refined with this information. In fact, the evolution of direct and indirect inputs used in the subsystems might be affected by different causes. The use of direct inputs is mainly connected to the I-O sectoral technology (Miller and Blair 2009). It often depends on internal, competitiveness-driven developments, specific to the sector itself. In the case of services used as inputs by the manufacturing sector, for example, changes are normally traced back to the outsourcing of non-core activities, to a growing demand for knowledge intensive innovative services, to the addition of greater amounts of ancillary services to companies' products, etc. (Falk and Peng 2013; Francois and Woerz 2008; Guerrieri and Meliciani 2005; Pilat and Wölfl 2005). The amount of work needed to produce indirect inputs, in contrast, depends on the general organization of the economic system (the structure of its internal division of labour) and on the processes of structural change concerning the whole economy. Changes of such amount over time capture a sort of 'country effect' on the production of final manufactured goods: to which extent the competitiveness of manufacture is affected by the general organization of the economy, and, conversely, to which extent any shock affecting the manufacturing sector is passed onto the general economic system.

2. Methodology

The labour units in the subsystems of the economy, distributed by kind of intermediate input, are usually obtained as follows (Sarra et al. 2018):

$$\boldsymbol{B} = \hat{\boldsymbol{l}}\hat{\boldsymbol{x}}^{-1}(\boldsymbol{I} - \boldsymbol{A})^{-1}\hat{\boldsymbol{f}}$$

where $\boldsymbol{A}$ is the coefficient matrix derived from the original I-O table $\boldsymbol{Z}$, $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ represents the Leontief inverse, $\hat{\boldsymbol{l}}$ is a diagonal matrix of the total hours worked in each sector in which the economy is separated, $\hat{\boldsymbol{x}}$ is the diagonal matrix of the total output (and $\hat{\boldsymbol{x}}^{-1}$ is its inverse), $\hat{\boldsymbol{f}}$ is the

diagonal matrix of the final output. The elements in the matrix $\boldsymbol{B}$ are in labour units, under the hypothesis of a given technology. The columns of the $\boldsymbol{B}$ matrix represent the subsystems and contain the amounts of inputs directly and indirectly required to produce the final output of each branch of the economy. The rows contain the amount of inputs of each branch which are directly and indirectly used to obtain the final output in the various subsystems.

An approach which allows one to separate the direct inputs from the indirect ones in the matrix of total inputs $\boldsymbol{B}$ can be based on the I-O production function. In I-O analysis, each sector is assumed to use a given amount of fixed assets to combine a) direct produced inputs and b) labour units to obtain total output (Pasinetti 1973). Building on this conceptual base, a matrix $\boldsymbol{\Delta}$ of direct labour requirements can be derived, which refers only to the production of final output, and is, therefore, comparable to $\boldsymbol{B}$. It should contain: a) the inter-industry flows used as direct inputs for the production of the final outputs (not the total output) of the branches of the economy (a portion of the flows reported in the $\boldsymbol{Z}$ matrix), measured in terms of labour units; b) the direct labour strictly needed to combine the produced inputs and obtain the final output of each industry (it is a portion of the labour figures reported in the vector $\boldsymbol{l}$). By subtracting $\boldsymbol{\Delta}$ from $\boldsymbol{B}$, the resulting matrix $\boldsymbol{N}$ will isolate the indirect inputs in a residual way.

To that purpose, the inter-industry transaction I-O table $\boldsymbol{Z}$ has to be pre-multiplied by the diagonal matrix $\hat{\boldsymbol{x}}^{-1}$. In this way, a matrix $\boldsymbol{S_I}$ is computed, and the elements on each row represent the shares of the total output of the corresponding sector (as a producer/seller) used as inputs by all the sectors (as purchasers/buyers) of the economy.

$$\boldsymbol{S_I = \hat{x}^{-1} Z}$$

A second (diagonal) matrix, $\widehat{\boldsymbol{S_F}}$, can be computed as follows:

$$\widehat{\boldsymbol{S_F}} = \hat{\boldsymbol{x}}^{-1}\hat{\boldsymbol{f}},$$

the elements on its main diagonal representing for each sector the share of the final output over the corresponding total output.

The principal diagonal of the matrix $\hat{\boldsymbol{l}}$ contains the labour units used by each sector to transform its inputs in its total (intermediate and final) output. Therefore, the sectors' direct uses of labour needed for the process of transformation of inputs in final outputs according to the proportions set by the I-O production function, can be found post-multiplying $\hat{\boldsymbol{l}}$ by $\widehat{\boldsymbol{S_F}}$.

$$\widehat{\boldsymbol{H_F}} = \hat{\boldsymbol{l}}\widehat{\boldsymbol{S_F}} = \hat{\boldsymbol{l}}\hat{\boldsymbol{x}}^{-1}\hat{\boldsymbol{f}}$$

The remaining labour units are destined to produce the intermediate inputs needed to obtain the total (intermediate and final) output of each sector. They are

$$\hat{\boldsymbol{l}}_I = \hat{\boldsymbol{l}} - \hat{\boldsymbol{l}}\hat{\boldsymbol{x}}^{-1}\hat{\boldsymbol{f}} = \hat{\boldsymbol{l}}\left(\boldsymbol{I} - \hat{\boldsymbol{x}}^{-1}\hat{\boldsymbol{f}}\right) = \hat{\boldsymbol{l}}\left(\boldsymbol{I} - \widehat{\boldsymbol{S_F}}\right)$$

The diagonal matrix $\hat{\boldsymbol{l}}_I$ can be used to measure (in terms of the labour units required for their production) the intermediate inputs of each sector according to the I-O production function by simply post-multiplying it by $\boldsymbol{S_I}$.

$$\boldsymbol{H_I = \hat{l}_I S_I = \hat{l}_I \hat{x}^{-1} Z}$$

To find the amount of intermediate inputs needed to obtain the output destined to final uses only, $\boldsymbol{H_I}$ needs to be post-multiplied by $\widehat{\boldsymbol{S_F}}$.

$$\boldsymbol{H_I^F = H_I \widehat{S_F}}$$

The matrix $\boldsymbol{\Delta}$ can at this point be computed adding $\boldsymbol{H_I^F}$ to $\widehat{\boldsymbol{H_F}}$. Finally, the matrix $\boldsymbol{N}$ of the indirect inputs used within the subsystem can be derived by subtracting $\boldsymbol{\Delta}$ from $\boldsymbol{B}$.

$$\boldsymbol{\Delta} = \boldsymbol{H_I} + \widehat{\boldsymbol{H_F}}$$

$$\boldsymbol{N} = \mathbf{B} - \boldsymbol{\Delta}$$

3. Empirical application

We present an empirical application of this methodology to the process of structural change that occurred in the period 2000-2014 in Germany and Italy, countries with strong manufacturing industries that have responded differently to the 2008 economic crisis. Germany recovered quickly, keeping the most knowledge-intensive and service-intensive activities within the country and outsourcing some of others to neighbouring countries (Stöllinger et al. 2013). In contrast, Italy's condition seems to have weakened. This pattern of structural change, already explored with the subsystem approach in the literature (Sarra et al. 2018), can be better further confirmed/qualified adopting the proposed methodology.

The empirical application is based on data from the World Input-Output Database (WIOD) November 2016 Release, which contains Input-Output tables and factor requirements for the years 2000 to 2014 (Timmer et al. 2016, 2015). Specifically, German and Italian National Input-Output Tables and Socio-Economic Accounts for the years 2000, 2007 and 2014 have been used in this study.

4. Results and discussion

The main results obtained are shown in Table 1.

[TABLE 1 HERE]

Total hours worked in the manufacturing subsystem grew by about 6% over the period in Germany, while it fell more than 13% in Italy, in the latter case giving evidence of a strong deindustrialization process. Moreover, Germany shows a higher 'direct vs indirect inputs' ratio than Italy across the whole period, and while this ratio increases in the former (from 160.95% in 2000 to 165.22% in 2014), it significantly decreased in the latter (from 135.42% to 131.43%).

As regards the relations between manufacturing and services, in Germany the share of services in the total hours worked of the manufacturing subsystem significantly increased (from 29.71% to 33.58%). The opposite emerges for Italy (a 2% decrease, and more than 5% in the sub-period 2007-2014). The ratio between direct and indirect input services also evolved differently in the two countries: it increased in Germany (from 45.66% to 49.29%), signalling the prevalence of the 'sector-specific effect' connected with competitiveness-driven changes in the I-O production function; it significantly decreased in Italy (from 44.22% to 38.41%), showing the prevalence of the 'country effect'.

The adoption of the proposed methodology evidences differences between Germany and Italy that go well beyond the deindustrialization affecting the latter country. In Italy, the productive processes that meet the final demand for manufactured goods are much more interconnected with the rest of the economy than in Germany, and this interconnection is becoming closer over time. Two consequences should be considered. Firstly, due to the intensification of the 'country effect', the competitiveness of manufacturing is increasingly dependent on the general competitiveness of the country system, which is a well-known weakness in Italy. Secondly, any shock to the final demand for manufactured goods is passed onto the rest of the economy more easily in Italy, which further contributes to the fragility of this country.

This impression is reinforced when the evolution of direct and indirect input services is considered. For Germany, the observed change in the sectoral production function (greater role of

direct-input services) confirms the idea – already present in the literature – of a competitiveness-induced evolution of manufacturing (greater use of internal produced knowledge-intensive business services). The situation is quite different in Italy. Here, the decline of direct input services is stronger than the decline of input services as a whole. If a higher share of direct input services is a distinctive feature of the current technological frontier, the evolution that has taken place in Italy can be a further signal of a worsening of the internal structure of manufacturing, with a potentially growing competitiveness gap.

5. Conclusions

The methodology proposed in this work allows one to deepen the analysis usually performed through the I-O subsystem approach. In particular, it allows to separate the value of direct and indirect inputs within the subsystems. Such a decomposition reveals some structural features which otherwise remain hidden. In particular, changes in I-O technology can be observed separately from the consequences of the evolution in the internal division of labour.

Our empirical application shows that over the observed period, according to the traditional subsystem approach, the German manufacturing subsystem held its position, while the Italian economy suffered a deindustrialization process. This general result is further refined by the decomposition of direct and indirect inputs within the subsystem, and in particular by that of direct and indirect input services. In particular, it shows that while the internal structure of the manufacturing production experienced modernization in Germany, in Italy it suffered a degradation which might potentially exacerbate the negative effects of deindustrialization.

References

Chang, H.-J. 2006. "Industrial policy in East Asia – lessons for Europe." In *An Industrial Policy for Europe? From Concepts to Action, EIB Papers*, edited by EIB. Luxembourg, EIB Papers, pp. 106–133.

Falk, M., and Peng, F. 2013. "The increasing service intensity of European manufacturing." *The Service Industries Journal* 33: 1686–1706. doi:10.1080/02642069.2011.639872

Francois, J., and Woerz, J. 2008. "Producer Services, Manufacturing Linkages, and Trade." *Journal of Industry, Competition and Trade* 8: 199–229. doi:10.1007/s10842-008-0043-0

Guerrieri, P., and Meliciani, V. 2005. "Technology and international competitiveness: The interdependence between manufacturing and producer services." *Structural Change and Economic Dynamics* 16: 489–502. doi:10.1016/j.strueco.2005.02.002

Miller, R.E., and Blair, P.D. 2009. *Input-Output Analysis: Foundations and Extensions*. Cambridge, Cambridge University Press.

Momigliano, F., and Siniscalco, D. 1986. "Mutamenti nella struttura del sistema produttivo e integrazione fra industria e servizi." In *Mutamenti Strutturali Del Sistema Produttivo*, edited by L.L Pasinetti. Bologna, Il Mulino, pp. 13–60.

Momigliano, F., and Siniscalco, D. 1982. "Note in tema di terziarizzazione e deindustrializzazione." *Moneta e Credito* 35: 143–182.

Montresor, S., and Vittucci Marzetti, G. 2011. "The deindustrialisation/tertiarisation hypothesis reconsidered: A subsystem application to the OECD7. *Cambridge Journal of Economics* 35: 401–421. doi:10.1093/cje/beq009

Pasinetti, L. 1973. "The notion of vertical integration in economic analysis." *Metroeconomica* 25: 1–29. doi:10.1111/j.1467-999X.1973.tb00539.x

Pilat, D., Wölfl, A. 2005. "Measuring the Interaction Between Manufacturing and Services." *OECD*

Science Technology and Industry Working Papers 05. doi:10.1787/882376471514

Rodrik, D., 2011. "The Manufacturing Imperative." *Project Syndicate* 10

Sarra, A., Di Berardino, C., and Quaglione, D. 2018. "Deindustrialization and the technological intensity of manufacturing subsystems in the European Union." *Economia Politica* 36: 205–243. doi:10.1007/s40888-018-0112-8

Stöllinger, R., Foster-McGregor, N., Holzner, M., Landesmann, M., Pöschl, J., and Stehrer, R. 2013. Research Report 391: *A 'Manufacturing Imperative' in the EU – Europe's Position in Global Manufacturing and the Role of Industrial Policy, Research Report.*

Timmer, M.P., Dietzenbacher, E., Los, B., Stehrer, R., and de Vries, G.J. 2015. "An Illustrated User Guide to the World Input-Output Database: The Case of Global Automotive Production." *Review of International Economics* 23: 575–605. doi:10.1111/roie.12178

Timmer, M.P., Los, B., Stehrer, R., and De Vries, G.J. 2016. "An Anatomy of the Global Trade Slowdown based on the WIOD 2016 Release." *Groningen Growth and Development Centre. Res. Memo*. 162: 1–67.

Table 1. Hours worked (H_wkd) in the manufacturing subsystem (M_SUB) and in market services (MS) in Germany (GER) and Italy (ITA); years 2000, 2007 and 2014.

		2000			2007			2014		
		B	**Δ**	**N**	**B**	**Δ**	**N**	**B**	**Δ**	**N**
H_wkd in the M_SUB	**GER**	10,916.91	6,733.42	4,183.49	11,348.58	6,836.50	4,512.08	11,583.34	7,215.94	4,367.40
	ITA	6,524.79	3,753.20	2,771.59	6,934.88	3,889.36	3,045.52	5,649.58	3,208.41	2,441.17
Shares of H_wkd in the M_SUB over H_wkd in the economy (%)	**GER**	27.35	22.03	44.75	28.14	22.25	46.99	27.12	22.15	43.09
	ITA	28.34	22.21	45.28	27.42	21.14	44.16	23.18	17.65	39.41
Shares of direct (Δ) and indirect (N) inputs in total H_wkd in the M_SUB (%)	**GER**		61.68	38.32		60.24	39.76		62.30	37.70
	ITA		57.52	42.48		56.08	43.92		56.79	43.21
Direct (Δ) vs indirect (N) inputs ratio; M_SUB	**GER**			160.95			151.52			165.22
	ITA			135.42			127.71			131.43
H_wkd in MS	**GER**	3,243.59	1,016.72	2,226.87	3,886.40	1,254.56	2,631.84	3,890.13	1,284.33	2,605.80
	ITA	2,167.92	664.75	1,503.17	2,541.36	780.96	1,760.40	1,772.60	491.89	1,280.70
Shares of H_wkd in MS over H_wkd in the M_SUB (%)	**GER**	29.71	15.10	53.23	34.25	18.35	58.33	33.58	17.80	59.66
	ITA	33.23	17.71	54.23	36.65	20.08	57.80	31.38	15.33	52.46
Shares of direct (Δ) and indirect (N) inputs in total H_wkd in MS (%)	**GER**		31.35	68.65		32.28	67.72		33.02	66.98
	ITA		30.66	69.34		30.73	69.27		27.75	72.25
Direct (Δ) vs indirect (N) inputs ratio; MS	**GER**			45.66			47.67			49.29
	ITA			44.22			44.36			38.41