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The Sectoral Innovation Database, 1994-2016. Methodological Notes

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**“THE SECTORAL INNOVATION DATABASE,
1994-2016.
METHODOLOGICAL NOTES”**

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The Sectoral Innovation Database, 1994-2016.

Methodological Notes

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Previous versions of the *Sectoral Innovation Database* were built with contributions from Valeria Cirillo, Dario Guarascio, Matteo Lucchese, Leopoldo Nascia, Stefano Supino

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Abstract

The Sectoral Innovation Database (SID) has been developed at the University of Urbino over the last 20 years and combines several major sources of industry-level data, shedding light on the dynamics of structural change, the nature and impact of innovation, the internationalisation of production, the evolution of the quantity and quality of employment, income distribution patterns and the role of digitalization. The database covers six major European countries – France, Germany, Italy, the Netherlands, Spain and the United Kingdom (representing 75% of EU28's GDP) – from 1994 to 2016, considering six time periods corresponding to upswings and downswings of business cycles. The first version of the SID provides data for 21 manufacturing and 17 service sectors for two-digit NACE Rev. 1 classes. As statistical surveys have moved to the two-digit NACE Rev. 2 classification, a second version of the Sectoral Innovation Database was produced, providing data for 18 manufacturing and 23 service sectors for two-digit NACE Rev. 2 classes. Major sources of data include the Community Innovation Surveys provided by Eurostat, the OECD's STAN database, the WIOD database, the Eurostat's EU Labour Force Surveys, and the EU KLEMS data on digitalization. The integrated information provided by the Sectoral Innovation Database offers a comprehensive view of industries' dynamics in Europe and allows for an in-depth investigation of key research questions related to technological change, economic performance, international production, income distribution and employment.

Keywords:

Innovation, Industries, Databases, Demand, Offshoring, Labour market

JEL classification: F15, J31, J51, L16, O33

Table of contents

1. Introduction	3
2. The relevance of the industry-level analysis	5
3. The list of sectors: the NACE Revision 1 database.....	6
4. The list of sectors: the NACE Revision 2 database.....	8
5. Innovation variables	12
6. Economic variables.....	15
7. Offshoring variables	18
8. Labour market variables	21
9. Digital variables.....	24
10. Time structure of the database and deflation methodology.....	26
11. The Revised Pavitt Taxonomy	30
12. Research based on the Sectoral Innovation Database	34
References	36
Appendix	39

List of Tables

Table 1. Countries covered by the SID database.....	3
Table 2. Data sources.....	4
Table 3. List of sectors (NACE Rev. 1 classification)	8
Table 4: The list of sectors (NACE Rev. 2 classification)	11
Table 5. List of innovation variables in SID Rev.1	14
Table 6: List of innovation variables in the SID Rev.2	15
Table 7. List of economic variables in the SID Rev.1.....	17
Table 8: List of economic variables in the SID Rev.2	18
Table 9. List of offshoring variables	20
Table 10. Correlation matrix of offshoring indicators' variations.....	21
Table 11. The professional groups	22
Table 12: The educational attainment groups.....	22
Table 13. List of labour market variables in the SID Rev.1	23
Table 14: List of labour market variables in the SID Rev.2.....	24
Table 15. List of ICT variables.....	26
Table 16. Time structure of the previous version of the SID Rev.1 (1994-2010).....	29
Table 17. Time structure of the current SID Rev.1 database (1994-2014)	29
Table 18: Time structure of the current SID Rev.2 database (1994-2016)	29
Table 19.The Revised Pavitt Taxonomy (NACE Rev. 1 industry classification)	32
Table 20.The Revised Pavitt Taxonomy (NACE Rev. 2 industry classification)	33

1. Introduction

The Sectoral Innovation Database (SID) has been first developed at the University of Urbino Carlo Bo and merges six different sources of industry-level data coming from various publicly available international datasets, offering a comprehensive overview of the mechanisms that link the innovation activity of sectors to their economic dynamics.

This paper summarizes the methodologies and data construction strategies applied for the Sectoral Innovation Database. Indeed, this is the product of long work. The idea of building an industry-level European database on innovation goes back to the year 2000 when the University of Urbino began exploratory work for a standardized and comparable database. Several European research institutes were involved in the European Project AITEG (Assessing the Impact of Technological change and globalization on Employment and Growth) that ended in May 2002. This project made extensive use of national Community Innovation Survey data to analyse the effects of technological activities on growth, employment and international production. This preliminary effort showed the feasibility and importance of developing a European industry-level innovation database.

As summarized in Table 1, the database includes industry-level data for six major European countries – France (FR), Germany (DE), Italy (IT), the Netherlands (NL), Spain (ES) and the United Kingdom (UK) –, which represent a very large part of the European economy (75% of EU28's GDP). The NACE Rev. 1 version of the SID database includes information for 21 manufacturing and 17 service sectors over the period 1994-2014, while the novel NACE Rev. 2 version of the database contains information for 18 manufacturing and 23 services sectors over the period 1994-2016. All data refer to total activities of industries, while all the monetary variables are in euros and constant prices (the base year is 2000).

Table 1. Countries covered by the SID database

Countries	Label
Germany	DE
France	FR
Italy	IT
Spain	ES
Netherlands	NL
United Kingdom	UK

Source: authors' elaboration.

The database provides information on the following items: first, the technological trajectories of industries and their structural evolution as shaped by the innovative efforts pursued by firms belonging to them; second, the economic performance of sectors mainly in terms of employment, productivity and value added; third, the distributive patterns of industries, i.e. their income distribution dynamics; fourth, the evolution of the

components of effective demand, which essentially contribute to drive the growth and decline of industries and thus the changing composition of the economies; fifth, the internationalization of production and the offshoring strategies of industries; sixth, the labour market institutions (namely union density), the spread of non-standard forms of work, educational and occupational structure of industries; seventh, the digitalization of the economy, related to the widespread diffusion of digital technologies in the patterns of both consumption and investment. The data sources used for building the SID are presented in Table 2.

Table 2. Data sources

Data	Source
Innovation	Community Innovation Survey (CIS) - Eurostat
Economic performance	OECD-STAN and WIOD
Demand and offshoring	WIOD
Labour market	EU Labour Force Survey (EU LFS) - Eurostat
Digitalisation	EU KLEMS and WIOD
Union density	ICTWSS 5.1

Source: authors' elaboration.

An important part of the database is represented by data drawn from the Community Innovation Survey (CIS) provided by Eurostat. This data source offers information collected directly from firms, with an effort to assure homogeneity in the definitions of innovation and in the way data are collected. These data allow to overcome the limitations of traditional measures of innovation, such as patents and public and private R&D expenditure (that also are a part of the set of indicators offered by Eurostat), and provide an exhaustive picture of the diversified innovation efforts of firms, both in technological and organizational activities. Through the integration with data on economic performance, demand patterns, distribution, labour market dynamics and offshoring, the SID database provides data from 1994 to 2016, considering six time periods corresponding to upswings and downswings of business cycles. In this way it delivers a comprehensive view of industries' dynamics and of the interaction between innovation and the evolution of economies, shedding light on a large number of empirical questions on the patterns and drivers of economic change in European countries.

In this paper Section 2 provides a brief literature review on the relevance of the industry-level analysis to investigate the evolutionary patterns of economies. Section 3 and Section 4 provide the list of sectors in NACE Rev. 1 and NACE Rev. 2 classification, respectively. From Section 5 to Section 9 different set of variables included in the SID are separately described. Section 10 reports the time structure of the database. Section 11

includes a description of the Revised Pavitt Taxonomy used to classify sectors according to their technological trajectories and economic structure. Finally, Section 12 presents the list of studies based on the SID.

2. The relevance of industry-level analysis

Industry-level analysis allows to properly investigate the changing composition of economies, accounting for both the demand- and supply-side factors which shape the process of structural change.

On the demand-side, industry-level analysis allows considering the evolution of the demand which is directed to a given industry; this can represent a limit to production growth as in the absence of a simultaneous expansion of demand, the growth of industries' production is constrained. The role of industry-specific demand and its relationship with production and employment growth are important issues that can be investigated with the approach we develop here. While an individual firm can always grow and increase its market share at the expense of competitors – the so-called 'business stealing' effect –, an industry's demand has a downward slope and results from the part of aggregate demand directed to the products and services of a given sector. Therefore, at the firm level, innovation can easily result in improved economic performance, whereas at the industry level, this is likely to happen only when a simultaneous expansion of demand (relative to other industries) is also taking place.

On the supply-side, firm-level studies have documented the high heterogeneity existing among enterprises (Bogliacino et al. 2017; Guarascio and Tamagni 2016), but often fail to provide a picture that is coherent with aggregate trends. Industry-level analyses, conversely, highlight changes in the structure of the economies linking them to macroeconomic performances. In particular, firm-level approaches are inadequate to investigate a number of research questions.

First, firm-level studies are often based on panels including a relatively small number of firms – often manufacturing firms alone - that, in most cases, are not representative of the universe. Second, when a panel is followed over time, by definition it excludes firms exiting and entering the market—events where innovation, or the lack of it, is likely to play a major role. Thus, a generalisation of the findings beyond the firms in the sample to other firms or to the whole economy level remains somewhat challenging. On the contrary, industry-level studies account for the totality of business in a given sector, levelling off gains and losses that may occur at the firm level, showing the changes in the structure of the economy and making links possible to overall macroeconomic patterns. Industry-level approaches are therefore capable to account for the technological heterogeneity of sectors in an effective way, whereas in firm-level studies, such heterogeneity is generally expressed in a limited way by inadequate indicators of industries' technological characteristics, or is left unexplored and bundled with all sorts

of other factors in industry dummies. Furthermore, while increasing vertical disintegration of firms and their different positions along value chains risk exacerbating heterogeneity, an industry-level approach permits to conduct a more integrated investigation of structural transformations related to production organization.

Moreover, industry-level analysis is coherent with the perspective suggested by the literature on sectoral systems of innovation, which stressed that the innovative behaviour of firms is fundamentally affected by the technological regime of the industry they belong to (Malerba 2002, 2004a, 2004b). More precisely, technological regimes – defined in terms of appropriability of innovations, cumulativeness of technological advances, technological opportunities and knowledge nature of firms' innovative efforts – shape the trajectories of innovation and thus determine the structure of the markets as well as the rate and direction of technological change of industries (Breschi et al. 2000; Malerba 2005; Malerba and Orsenigo 1997). This perspective also allows assessing the dominant competitiveness strategy pursued by industries, shedding light on their different distributive outcomes.

Consistently with this framework, evolutionary approaches developed a meaningful classification of industries, framing them within a limited number of classes according to the technological paradigm they share (Dosi 1982, 1988). Such a framework led to the construction of taxonomies of industries, identified on the basis of their common technological trajectories, competitiveness patterns and economic performance. In this regard, Pavitt (1984) focused on the structure of markets and on the nature, sources and appropriability of innovation to conceptualize four different technology-based classes, according to which manufacturing industries were classified. Bogliacino and Pianta (2010, 2016) investigated the relationships between innovation patterns and economic performance of service industries and provided a Revised Pavitt Taxonomy which extends the original Pavitt classification to the service sectors; the list of industry groups is the following: Science Based (SB), Specialized Suppliers (SS), Scale and Information Intensive (SI), Supplier Dominated (SD). Moreover, this classification is very useful for the analysis of structural change of economies, since it provides the possibility to reduce the heterogeneity and focus on the growth patterns of industries belonging to different technological classes.

3. The list of sectors: the NACE Revision 1 database

Table 3 provides a list of sectors included in the SID Rev.1 database. The 21 manufacturing and 17 service sectors of the two-digit NACE Rev. 1 classification are listed, with the NACE codes (third column), the Revised Pavitt class to which each industry belongs (fourth column), and with the aggregation of sectors in high- and low-tech clusters (fifth column); the latter defines as high-tech the industries belonging to

Science Based (SB) and Specialized Suppliers (SS) groups, and as low-tech the industries belonging to Supplier Dominated (SD) and Scale and Information Intensive (SI) sectors.

In order to ensure comparability, all the data from 2008 onwards have been converted into NACE Rev. 1 using the conversion matrix provided by Perani and Cirillo (2015).¹ All data refer to the total activities of industries.²

¹ Since the conversion procedure might result in some data distortions, implausibly large values (in absolute terms) which appeared for some industries have been excluded.

² The selection of countries and sectors has been made in order to avoid limitations in access to data (due to the low number of firms in a given sector of a given country, or to the policies on data release by National Statistical Institutes). Sectors excluded from the NACE Rev. 1 version of the database are 1-14 NACE Rev. 1.1 (Agriculture, hunting, forestry and fishing and Mining and quarrying) and 75-99 (Community Social and Personal Services). NACE Rev. 1.1 classification was used by EU Member Countries until 2008 and it is compatible with ISIC Rev. 3 classification (United Nations).

Table 3. List of sectors (NACE Rev. 1 classification)

Nr.	Sectors (NACE Rev. 1)	NACE codes	Revised Pavitt class	High-tech / Low-tech
Manufacturing sectors				
1	Food products, beverages and tobacco	15-16	SD	LT
2	Textiles	17	SD	LT
3	Wearing apparel, dressing and dyeing of fur	18	SD	LT
4	Leather and leather products and footwear	19	SD	LT
5	Wood and products of wood and cork	20	SD	LT
6	Pulp, paper and paper products	21	SI	LT
7	Printing and publishing	22	SI	LT
8	Coke, refined petroleum products and nuclear fuel	23	SI	LT
9	Chemicals and chemical products	24	SB	HT
10	Rubber and plastics products	25	SI	LT
11	Other non-metallic mineral products	26	SI	LT
12	Basic metals	27	SI	LT
13	Fabricated metal products (except machinery and equipment)	28	SD	LT
14	Machinery and equipment, n.e.c.	29	SS	HT
15	Office, accounting and computing machinery	30	SB	HT
16	Electrical machinery and apparatus, nec	31	SS	HT
17	Radio, television and communication equipment	32	SB	HT
18	Medical, precision and optical instruments	33	SB	HT
19	Motor vehicles, trailers and semi-trailers	34	SI	LT
20	Other transport equipment	35	SS	HT
21	Manufacturing nc and recycling	36-37	SD	LT
Service sectors				
22	Sale, maintenance and repair of motor vehicles; retail sale of fuel	50	SD	LT
23	Wholesale, trade & commission excl. Motor vehicles	51	SD	LT
24	Retail trade excl. Motor vehicles; repair of household goods	52	SD	LT
25	Hotels and restaurants	55	SD	LT
26	Land transport	60	SD	LT
27	Sea transport	61	SD	LT
28	Air transport	62	SD	LT
29	Supporting and auxiliary transport activities	63	SD	LT
30	Post and telecommunications	64	SB	HT
31	Financial intermediation (except insurance and pension funding)	65	SI	LT
32	Insurance and pension funding (except compulsory social security)	66	SI	LT
33	Activities related to financial intermediation	67	SI	LT
34	Real estate activities	70	SS	HT
35	Renting of machinery and equipment	71	SS	HT
36	Computer and related activities	72	SB	HT
37	Research and development	73	SB	HT
38	Other business activities	74	SS	HT

Source: authors' elaboration.

4. The list of sectors: the NACE Revision 2 database

Table 4 provides a list of sectors included in the SID Rev.2 database based on the NACE Rev.2 (ISIC Rev. 4) classification. The 18 manufacturing and 23 service sectors of the two-digit NACE Rev. 2 classification are listed, with the NACE codes (third column), the Revised Pavitt class to which each industry belongs (fourth column), and with the

aggregation of sectors in high- and low-tech clusters (fifth column), defined as in the previous table.

All the data that had been released in the NACE Rev.1 until 2008 have been converted in the NACE Rev.2 using country-specific conversion matrices. New variables on the diffusion of digital technologies in industries were added and are available in the SID Rev.2 version only.

Procedure for addressing the change in classification

The revision of the NACE classification was introduced in 2008. In the Sectoral Innovation Database (SID) Rev.2, all the data in NACE Rev.1, from 2008 backwards, were converted in the NACE Rev.2 using the country-specific conversion matrices (see Table A.1-A.6 in the Appendix).

The availability of the EU Labour Force Survey microdata on sectoral employment in 2008 in both classifications - NACE Rev.1 and NACE Rev.2 - allowed us to construct six ‘bridge matrices’ following the procedure provided by Perani and Cirillo, 2015. While for some sectors the conversion was straightforward - mapping 1:1 (e.g. all activities of the industry ‘Food Products’ in Rev.1 correspond to activities of industry ‘*Manufacturing of Food products*’ in Rev.2), in the case of 1:m mapping – e.g. total employment for the ‘*Manufacturing of wearing apparel*’ Rev.2 industry was calculated as the sum of 99,36% from ‘*Manufacturing of wearing apparel*’ (Rev.1) and 19% from the ‘*Manufacture of textiles*’ sector (Rev.1).

The backcasting procedure used to convert NACE Rev.1 data into NACE Rev.2 can be formalized as follows:

$$z = (z_1 \quad z_2 \quad \dots \quad z_m)$$

$$W = \begin{pmatrix} w_{11} & \dots & w_{1m} \\ \vdots & \ddots & \vdots \\ w_{n1} & \dots & w_{nm} \end{pmatrix}$$

$$y = (y_1 \quad y_2 \quad \dots \quad y_n)$$

$$z \times W^T = y$$

Where z is a vector of a variable (i.e. total R&D expenditure) expressed in NACE Rev.1; W is a matrix of weights (w) distributing the quantity of z to y in NACE Rev.2, where the sum of each column in matrix equals 1 (100%); y is a resulting vector in NACE Rev.2; m and n denote sectors in NACE Rev.1 and Rev.2; as an illustration, we work with the following system of equations:

$$z_1w_{11} + z_2w_{12} + z_3w_{13} + z_4w_{14} + \dots + z_mw_{1m} = y_1$$

$$z_1w_{21} + z_2w_{22} + z_3w_{23} + z_4w_{24} + \dots + z_mw_{2m} = y_2$$

$$\vdots$$

$$z_1w_{m1} + z_2w_{m2} + z_3w_{m3} + z_4w_{m4} + \dots + z_mw_{nm} = y_n$$

This procedure has then been extended to all innovation and labour market variables in the SID Rev.2 database from 2008 backwards.

Table 4: The list of sectors (NACE Rev. 2 classification)

Nr.	Sectors (NACE Rev. 2 classification)	NACE codes	Revised Pavitt class	High-tech / Low-tech
Manufacturing sectors				
1	Manufacture of food products, beverages and tobacco products	C10-C12	SD	LT
2	Manufacture of textiles, wearing apparel and leather products	C13-C15	SD	LT
3	Manufacture of wood and of products of wood and cork, except furniture	C16	SD	LT
4	Manufacture of paper and paper products	C17	SI	LT
5	Printing and reproduction of recorded media	C18	SI	LT
6	Manufacture of chemicals and chemical products	C20	SB	HT
7	Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21	SB	HT
8	Manufacture of rubber and plastic products	C22	SI	LT
9	Manufacture of other non-metallic mineral products	C23	SI	LT
10	Manufacture of basic metals	C24	SI	LT
11	Manufacture of fabricated metal products, except machinery and equipment	C25	SD	LT
12	Manufacture of computer, electronic and optical products	C26	SB	HT
13	Manufacture of electrical equipment	C27	SS	HT
14	Manufacture of machinery and equipment n.e.c.	C28	SS	HT
15	Manufacture of motor vehicles, trailers and semi-trailers	C29	SI	LT
16	Manufacture of other transport equipment	C30	SS	HT
17	Manufacture of furniture; other manufacturing	C31-C32	SD	LT
18	Repair and installation of machinery and equipment	C33	SS	HT
Service sectors				
19	Wholesale and retail trade and repair of motor vehicles and motorcycles	G45	SD	LT
20	Wholesale trade, except of motor vehicles and motorcycles	G46	SD	LT
21	Retail trade, except of motor vehicles and motorcycles	G47	SD	LT
22	Land transport and transport via pipelines	H49	SD	LT
23	Water transport	H50	SD	LT
24	Air transport	H51	SD	LT
25	Warehousing and support activities for transportation	H52	SD	LT
26	Postal and courier activities	H53	SD	LT
27	Accommodation and food service activities	I55-I56	SD	LT
28	Publishing activities	J58	SI	LT
29	Audiovisual and broadcasting activities	J59-J60	SI	LT
30	Telecommunications	J61	SB	HT
31	Computer programming, consultancy and related activities; information service activities	J62-J63	SB	HT
32	Financial service activities, except insurance and pension funding	K64	SI	LT
33	Insurance, reinsurance and pension funding, except compulsory social security	K65	SI	LT
34	Activities auxiliary to financial services and insurance activities	K66	SI	LT
35	Real estate activities	L68	SS	HT
36	Legal and accounting activities; management consultancy activities	M69-M70	SS	HT
37	Architectural and engineering activities; technical testing and analysis	M71	SS	HT
38	Scientific research and development	M72	SB	HT
39	Advertising and market research	M73	SS	HT
40	Other professional, scientific and technical activities; veterinary activities	M74-M75	SS	HT
41	Administrative and support service activities	N	SD	LT

Source: authors' elaboration.

5. Innovation variables

The SID includes a set of variables coming from the Community Innovation Surveys (CIS) collected by Eurostat and related to the innovative efforts pursued by industries. CIS data represent the core of the SID database, as they provide important information on a wide range of measures on the innovative activities of sectors. The SID includes information from six CIS waves: CIS 2 (1994-1996), CIS 3 (1998-2000), CIS 4 (2002-2004), CIS 7 (2008-2010), CIS 9 (2012-2014) and CIS 10 (2014-2016). The lack of annual surveys led us to give up attempts to develop a yearly database; we opted for identifying – over the years 1994 to 2016 - six time periods corresponding to upswings and downswings of business cycles. This choice is due on the one hand to the lack of major annual changes in industries' innovative performances, where cumulative patterns are important. On the other hand, this allows us to focus on the lags and time frames in which innovations develop their economic effects and on the economic dynamics associated to business cycles (see section 10 below).

Community Innovation Surveys provide information which allows disentangling the complexity regarding the process of technological change. On the one hand, it permits to distinguish between product and process innovation, assessing the dominant competitiveness strategies pursued by different industries. On the other hand, it allows to distinguish between the 'input' and 'output' of innovative efforts; in other words, our database enables to introduce a distinction between the innovative efforts pursued by industries to introduce innovations (e.g. R&D expenditure per employee) and the outcome of innovative procedures (e.g. share of turnover due to new or improved products at industry-level).

These surveys are based on direct questions to firms about their activities: a questionnaire is used, ensuring that definitions of innovations are similar and the procedures of reply are homogenous.³ CIS is developed by Eurostat in close cooperation with National Statistical Offices and research institutions of countries involved. Starting from CIS 3, it covers the EU Member States, EU Candidate Countries, Iceland and Norway. Because of differences in the coverage criteria and collection procedures followed by some countries and of problems of confidentiality, Eurostat made CIS 2 and CIS 3 data available only at a very high level of aggregation, while CIS 4 data are directly available on New Cronos.

At the start of our work on SID, the involvement of European research institutions or national statistical institutes in the AITEG and the SIEPI Projects has made it possible to overcome the data constraints and provide a large set of information on innovation at a detailed sectoral break-down also for CIS 2 and CIS 3. The co-operation among national data providers, respecting country-specific limitations in terms of confidentiality, data

³ The Survey Questionnaires are available at <https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey>

access and dissemination politics, has been guided by the University of Urbino through a set of methodological guidelines. All countries (except for Germany, whose data have been obtained directly from Eurostat) have been involved through data-sharing agreements with the University of Urbino. The assembling of the database has been carried out using common data protocols and statistical procedures on data integration and standardization. The selection of countries and sectors has been made to make sure that no confidentiality problems in the access to data can emerge (due to the policies on data release by national statistical institutes or to the low number of firms in a given sector of a given country). Conversely, CIS 4 data have been obtained directly from New Cronos, except for the United Kingdom, whose data have been obtained from the national data provider.

Since 2008, the industry classification moved from NACE Rev. 1 to NACE Rev. 2; from CIS 6 onwards, i.e. CIS 6, CIS 7, CIS 8, CIS 9 and CIS 10, sectors are codified in the latter classification. Therefore, in order to construct a homogeneous database in Rev.1, we had to convert innovation variables expressed in NACE Rev. 2 classification in NACE Rev. 1 codes applying a backcasting procedure based on a conversion matrix introduced by Perani and Cirillo (2015). We performed this procedure for CIS 6, CIS 7 and CIS 9. Instead, in the case of the SID Rev.2, we converted innovation data from first three CIS waves (CIS2, CIS3 and CIS4) - originally expressed in NACE Rev.1 - to NACE Rev.2 using the country-specific conversion matrices (see section 4). Due to the conversion procedure, we tested for the presence of structural breaks in the series through Spearman correlations and at 5% of confidence level we rejected the possibility of the absence of correlations between different waves of CIS. We controlled for trend stability both at a sectoral level over time and at a country level over time. In both cases, we rejected the presence of structural breaks over time. To the best of our knowledge, this has been the first attempt to convert CIS data in NACE Rev. 1 codes in order to face the lack of a unified procedure for long time series of innovation data.

One shortcoming is that the innovation variables available from CIS 6 onwards are fewer than previous waves. In addition, the questionnaire provided by Eurostat to be fulfilled by the firms for collecting data on their innovation efforts has changed over time (especially from CIS 7 onwards). As a consequence, the information included in the CIS has changed as well, with the result that some variables included in a given wave of CIS may not be available for the subsequent ones. For this reason, Table 5 lists the innovation variables available in the SID Rev.1, where the last column provides information on the availability of each of them over time.

In particular, the variables available from 1994 to 2008 are drawn by the following CIS waves: CIS 2 (1994-1996), CIS 3 (1998-2000), CIS 4 (2002-2004), CIS 6 (2006-2008). The available variables covering a longer time span, namely from 1994 to 2016, are drawn from the following six CIS waves: CIS 2 (1994-1996), CIS 3 (1998-2000), CIS 4 (2002-2004), CIS 7 (2008-2010), CIS 9 (2012-2014) and CIS 10 (2014-2016).

As shown later (see Section 10), these survey waves were matched with economic, demand and labour market data at industry-level.⁴ As reported by Table 5, a large number of innovation variables is available for the whole period covered by the Rev.1 database, i.e. 1994-2014.⁵

Table 6 reports the innovation variables available in the SID Rev.2., where the number of standard variables is lower, but they are available for the whole 1994-2016 period.

Table 5. List of innovation variables in SID Rev.1

	Label	Expressed as	Availability
Innovation activity			
Share of firms introducing a new or significantly improved product or process	QINNOV	Number of firms (%)	1994-2014 (from CIS 2 to CIS 9)
Share of firms introducing a product or service innovation	QINPDT	Number of firms (%)	1994-2014 (from CIS 2 to CIS 9)
Share of firms introducing new or significantly improved products only	QINPDTONLY	Number of firms (%)	1994-2014 (from CIS 2 to CIS 9)
Share of firms introducing a process innovation	QINPCS	Number of firms (%)	1994-2014 (from CIS 2 to CIS 9)
Share of firms introducing new or significantly improved processes only	QINPCSONLY	Number of firms (%)	1994-2014 (from CIS 2 to CIS 9)
Innovation output			
Turnover due to new or improved products	TURNIN	Total turnover (%)	1994-2014 (from CIS 2 to CIS 9)
Innovation input			
Real expenditure in research and experimental development within the enterprise per employee	EXRDIN	Thousand euro per employee	1994-2014 (from CIS 2 to CIS 9)
Real expenditure in acquisition of machinery and equipment linked to innovations per employee	EXMACH	Thousand euro per employee	1994-2014 (from CIS 2 to CIS 9)
Real total innovation expenditure (standardized between waves) per employee	EXTO	Thousand euro per employee	1994-2014 (from CIS 2 to CIS 9)
Objectives of innovation			
Share of firms opening up new markets or increase market Share	QEMAR	Number of firms (%)	1994-2014 (from CIS 2 to CIS 9)
Share of firms reducing labour costs	QELBR	Number of firms (%)	1994-2008 (from CIS 2 to CIS 6)
Sources of innovation			
Share of firms sourcing from within the enterprise	QSENT	Number of firms (%)	1994-2008 (from CIS 2 to CIS 6)
Share of firms sourcing from suppliers of equipment, materials, components or software	QSSUP	Number of firms (%)	1994-2008 (from CIS 2 to CIS 6)
Other variables			
Average size of the firms	SIZE	Average number of employees	1994-2014 (from CIS 2 to CIS 9)

Source: authors' elaboration.

⁴ We do not use ANBERD or EU KLEMS as data source for innovation variables because they do not encompass any kind of data concerning embodied technical change (contrary to data from the CIS waves, which include data on expenditure in machinery and equipment) and we do not want to 'mix' different sources of data for building up the innovation variables. Nonetheless, the conversion from CIS firm-level data into industry-level data is performed so as to ensure consistency with other industry-level indicators in the dataset (Bogliacino and Pianta, 2013a).

⁵ In rare cases, data on some innovation variables were not available in CIS 7 or CIS 9 for a given country. Consequently, we fulfilled the missing information exploiting data included in CIS 6 and CIS 8 referring to the same country variables, performing a number of statistical tests to check the reliability of the imputation procedure.

Table 6: List of innovation variables in the SID Rev.2

Label	Code	Unit	Availability
Average size of the firms	SIZE	Thousand of employees	1994-2016
Share of firms introducing an innovation	QINNO	Share of firms (%)	1994-2016
Share of firms introducing a product or service innovation	QINPDT	Share of firms (%)	1994-2016
Share of firms introducing a product or service innovation only	QINPDTONLY	Share of firms (%)	1994-2016
Share of firms introducing a process innovation	QINPCS	Share of firms (%)	1994-2016
Share of firms introducing a process innovation only	QINPCSONLY	Share of firms (%)	1994-2016
Share of firms introducing an organisational innovation	QINORG	Share of firms (%)	2012-2016
Share of firms introducing an organisational innovation only	QINORGONLY	Share of firms (%)	2012-2016
Real total innovation expenditures	EXPINNO	Thousand euro per employee	1994-2016
Internal R&D expenditure	EXPRDIN	Thousand euro per employee	1994-2016
External R&D expenditure	EXPRDEX	Thousand euro per employee	1994-2016
Total R&D expenditure	EXPRD	Thousand euro per employee	1994-2016
Expenditure in acquisition of machinery and equipment	EXPMACH	Thousand euro per employee	1994-2016

Source: authors' elaboration.

Notes: QINPDT and QINPCS are not reported for the following waves: CIS3, CIS4, CIS5, CIS6. We construct QINPDT as a sum of QINPDTONLY and QPANDP (Product and process innovative enterprises) and QINPCS as a sum of QINPCSONLY and QPANDP.

6. Economic variables

The SID database includes a series of economic variables related to the economic performance of industries – e.g. gross output, value added and employment; the distributional dynamics of industries; and the most important demand variables, i.e. the evolution of domestic final consumption and exports. These variables, briefly described below, are summarized in Table 7 (SID Rev.1) and Table 8 (SID Rev.2).

Economic performance

The SID database includes a series of variables related to the economic performance of industries, such as gross output, value added, labour productivity, employment as well as investments in fixed capital - i.e. Gross Fixed Capital Formation (GFCF). All the economic variables are available for the period 1995-2015 in the SID Rev.2 version. Data are drawn from the Structural Analysis Database (STAN) provided by the OECD and from the Socio-Economic Accounts (SEA) released by the World Input-Output Database (WIOD) (Timmer et al., 2015, 2016).

Distributive variables

Concerning the distributive dynamics of sectors, the SID includes data on the growth pattern of wages (both per employee and per worked hour) and profits, where the latter is computed as gross operating surplus at the industry level. Unfortunately, data on the skill structure of the employment and of employees' compensation per skill – low-, medium- and high-skilled workers are grouped according to the education level based on the

ISCED classification⁶ – are only available for the period 1995-2009. Data are drawn from the Structural Analysis Database (STAN) provided by the OECD and from the Socio-Economic Accounts (SEA) released by WIOD.

Demand variables

The growth of aggregate demand is largely recognized as crucial for understanding the development and decline of industries over time; this awareness raises the need to disentangle the role of different components of effective demand to properly assess the growth patterns of sectors and suggest policy recommendations. The SID accomplishes this task reporting industry-level data for total (final and intermediate) demand, domestic demand, exports, and imports.

In particular, we take advantage of the World Input-Output Tables (WIOT) provided by WIOD and computed industry-specific flows of demand for each country included in the database. For example, domestic final demand has been computed in the following way: for each industry of a given country, we calculate the sum of four sources of final demand coming from that country, namely final consumption expenditure by households, final consumption expenditure by non-profit organizations serving households (NPISH), final consumption expenditure by government and gross fixed capital formation. As regards exports, for each industry of a given country we computed the sum of both intermediate and final flows of goods (expressed in monetary terms) produced by that industry and directed abroad, i.e. bought by any other industry of any other country in the world.

⁶ More information on the ISCED classification are available at [https://ec.europa.eu/eurostat/statistics-explained/index.php/International_Standard_Classification_of_Education_\(ISCED\)](https://ec.europa.eu/eurostat/statistics-explained/index.php/International_Standard_Classification_of_Education_(ISCED))

Table 7. List of economic variables in the SID Rev.1

	Label	Expressed as	Availability
Economic performance			
Value added	RVA	Annual rate of growth (%)	1995-2014
Gross output	RVGO	Annual rate of growth (%)	1995-2014
Worked hours	RVWH	Annual rate of growth (%)	1995-2014
Employment	RVEMP	Annual rate of growth (%)	1995-2014
Labour productivity (per worked hour)	RVPRWH	Annual rate of growth (%)	1995-2014
Labour productivity (per employee)	RVPREMP	Annual rate of growth (%)	1995-2014
Gross Fixex Capital Formation	RVGFCF	Annual rate of growth (%)	1995-2009
Distribution			
Gross operating surplus (profits)	RVOS	Annual rate of growth (%)	1995-2014
Total wages	RVLCEMP	Annual rate of growth (%)	1995-2014
Wages (per worked hours)	RVLCWH	Annual rate of growth (%)	1995-2014
Wages (per employee)	RVLCPEMP	Annual rate of growth (%)	1995-2014
Distribution and employment per skill			
Number of high-skilled (HS) employees	EMPHS	Annual rate of growth (%)	1995-2009
Number of medium-skilled (MS) employees	EMPMS	Annual rate of growth (%)	1995-2009
Number of low-skilled (LS) employees	EMPLS	Annual rate of growth (%)	1995-2009
Compensation of HS employees	WHS	Annual rate of growth (%)	1995-2009
Compensation of MS employees	WMS	Annual rate of growth (%)	1995-2009
Compensation of LS employees	WLS	Annual rate of growth (%)	1995-2009
Compensation of HS employees per worked hour	WHSKPC	Annual rate of growth (%)	1995-2009
Compensation of MS employees per worked hour	WMSKPC	Annual rate of growth (%)	1995-2009
Compensation of LS employees per worked hour	WLSKPC	Annual rate of growth (%)	1995-2009
Demand			
Total final demand	RVTOTFINDEM	Annual rate of growth (%)	1995-2014
Total intermediate inputs demand	RVTOTINTDEM	Annual rate of growth (%)	1995-2014
Domestic total demand	RVDOMTOTDEM	Annual rate of growth (%)	1995-2014
Domestic final demand	RVDOMFINDEM	Annual rate of growth (%)	1995-2014
Domestic household consumption	RVDOMHHCONS	Annual rate of growth (%)	1995-2014
Total imports	RVIMP	Annual rate of growth (%)	1995-2014
Final imports	RVFINIMP	Annual rate of growth (%)	1995-2014
Exports	RVEXP	Annual rate of growth (%)	1995-2014
Export share	RVEXPSH	Simple difference	1995-2014

Source: authors' elaboration.

Table 8: List of economic variables in the SID Rev.2

Label	Code	Unit	Availability	Source
Economic performance				
Value added	VVA	Annual rate of growth (%)	1995-2015	OECD STAN
Production (gross output)	VPROD	Annual rate of growth (%)	1995-2015	OECD STAN
Employees	VEMP	Annual rate of growth (%)	1995-2015	OECD STAN
Hours worked (employees)	VWH	Annual rate of growth (%)	1995-2015	OECD STAN
Labour productivity (per employee)	VPREMP	Annual rate of growth (%)	1995-2015	OECD STAN
Labour productivity (per hour worked)	VPRWH	Annual rate of growth (%)	1995-2015	OECD STAN
Gross fixed capital formation	VGFCF	Annual rate of growth (%)	1995-2015	OECD STAN
Gross fixed capital formation per WH	VGFCFWH	Annual rate of growth (%)	1995-2015	OECD STAN
Gross fixed capital formation per employee	VGFCFEMPE	Annual rate of growth (%)	1995-2015	OECD STAN
Distribution				
Total compensation of employees	VLC	Annual rate of growth (%)	1995-2015	OECD STAN
Labour compensation (per employee)	VLCEMP	Annual rate of growth (%)	1995-2015	OECD STAN
Labour compensation (per worked hour)	VLCWH	Annual rate of growth (%)	1995-2015	OECD STAN
Wages and salaries	VWAGE	Annual rate of growth (%)	1995-2015	OECD STAN
Gross operating surplus and mixed income	VGOPS	Annual rate of growth (%)	1995-2015	OECD STAN
Demand				
Total final demand	VTOTFINDEM	Annual rate of growth (%)	2000-2014	WIOT
Total intermediate demand	VTOTINTDEM	Annual rate of growth (%)	2000-2014	WIOT
Domestic total demand	VDMTOTDEM	Annual rate of growth (%)	2000-2014	WIOT
Domestic final demand	VDMFINDEM	Annual rate of growth (%)	2000-2014	WIOT
Domestic household demand	VDMHHCONS	Annual rate of growth (%)	2000-2014	WIOT
Total imports	VIMP	Annual rate of growth (%)	2000-2014	WIOT
Final imports	VFINIMP	Annual rate of growth (%)	2000-2014	WIOT
Exports	VEXP	Annual rate of growth (%)	2000-2014	WIOT

Source: authors' elaboration.

Note: All variables are expressed as compound average annual rates of change.

7. Offshoring variables

Offshoring variables included in both the SID Rev.1 and the SID Rev.2 version were computed exploiting the World Input-Output Tables (WIOT) provided by the World Input-Output Database (WIOD)(Timmer et al. 2015, 2016). WIOD includes both the WIOT and data on Socio-Economic Accounts (SEA) at industry level. On the one hand, the former contains information about inter-industrial trade flows at current prices disaggregated by country and allow to study the supply and use of products broken down according to their origin. On the other hand, Socio-Economic Accounts (SEA) provide data regarding industries' output, value added, wages, profits, employment, hours worked, capital stock and investments. Notably, data from WIOD are available for the whole set of countries considered in the SID, are statistically representative of the universe of firms and its consistency with respect to other SID sections can be assured (in particular, the coherence of WIOD and OECD-STAN data has been verified through several statistical tests).

More precisely, the wide amount of information included in the first release of the WIOD database – which was published in 2013 and that covers 40 countries over the period 1995-2011 – was easily merged with the other SID Rev.1 sections due to the same industries classification (the industry classification of the former is ISIC Rev. 3.1, which

is compatible with the NACE Rev. 1 classification), while the new release – classified according to the ISIC Rev. 4 – has been matched with the NACE Rev. 2 version of the SID. Concerning the last release of the WIOD, which was published in 2016, it covers 43 countries and a model for the rest of the world for the period 2000-2014. Data for 56 sectors are classified according to the International Standard Industrial Classification Revision 4 (ISIC Rev. 4), which is compatible with the NACE Rev. 2 industry classification.

With regards to the match between the 2016 release of WIOD in ISIC Rev. 4 and the SID database classified in NACE Rev. 1, a disaggregation procedure – performed using country-specific (i.e. for each country) and time-specific (for each year) industry weights, the latter built on the basis of the number of persons engaged at industry-level provided by OECD-STAN database – has been performed. Such disaggregation procedure – which mirrors that performed to match the industry classification of the SID database with the data on digital investment provided by EU KLEMS (see Section 9) – was necessary to convert the 56 sectors classification of WIOD in ISIC Rev. 4 to the standard 96 sectors NACE Rev. 2 classification and then to convert this output in the NACE Rev. 1 industry classification through the conversion matrix provided by Perani and Cirillo (2015).

As regards the construction of offshoring variables, they are computed as the ratio between the sum of the expenditure devoted by each industry to the acquisition of different types of intermediate inputs from abroad over the expenditure for the total (domestically produced and foreign) intermediate inputs devoted by each user sector (Feenstra and Hanson 1996). In particular, we computed four different offshoring indicators. The first one is the broad offshoring indicator, which consists in the ratio between the expenditure for the intermediate inputs imported by a given industry from whatever foreign industries and the expenditure for the total intermediate inputs used by that industry. The second one consists in the “narrow” indicator of international offshoring proposed by Feenstra and Hanson (1999), which is computed as the ratio between the expenditure of a given industry for the intermediate inputs imported from foreign industries of the same type (corresponding to the diagonal terms of the import-use matrix) and the expenditure for the total intermediate inputs used by that industry.⁷

Furthermore, the technological content of imported intermediate inputs is crucial to understand the international outsourcing strategies of industries as well as the position they occupy along global value chains (Guarascio et al. 2015). We thus built two offshoring measures explicitly related to the technological dimension, namely a high-tech and a low-tech offshoring indicator, which can be formalized as follows:

⁷ It is worth noting that Feenstra and Hanson (1999) stress the reliability of narrow offshoring indicator since it is conceived to better capture the definition of production fragmentation, an event which mostly occurs within industries.

$$OFFSH_{i,j,t}^k = \frac{\text{Imported intermediate inputs}_{i,j,t}^k}{\text{Total intermediate inputs}_{i,j,t}}$$

$$k \in \{HT \text{ foreign industries}; LT \text{ foreign industries}\}$$

where the subscript i stands for the industry, j for country and t for time, whilst ‘HT’ and ‘LT’ stand respectively for high- and low-tech industries distinguished according to the Pavitt’s taxonomy as revised by Bogliacino and Pianta (2010, 2016). More precisely, we followed the revision of Feenstra and Hanson’s (1996) offshoring indicator proposed by Guarascio et al. (2015) as to discriminate intermediate inputs according to their origin (domestic or imported) and their technological content. With regard to this second aspect, the criterion adopted was the following: Science based or Specialized suppliers industries are classified as high-tech industries (HT) and the imported intermediate inputs coming from these industries represent the numerator of the high-tech offshoring indicator, while Scale and information intensive industries are classified as low-tech industries (LT) and the imported intermediate inputs coming from these industries represent the numerator of the low-tech offshoring indicator.⁸

The same procedure has also been followed to build a manufacturing offshoring and a service offshoring variable. To this aim, we applied the aforementioned formal expression to different numerators having $k \in \{\text{manufacturing foreign industries}; \text{service foreign industries}\}$.

Table 9. List of offshoring variables

Offshoring variables	Label	Expressed as	Availability
Broad offshoring	RVIITITOT	Simple difference	1995-2014
Narrow offshoring	RVIITINAR	Simple difference	1995-2014
Low-tech offshoring	RVIITILT	Simple difference	1995-2014
High-tech offshoring	RVIITIHT	Simple difference	1995-2014
Manufacturing offshoring	RVIITIMANUF	Simple difference	1995-2014
Service offshoring	RVIITISERV	Simple difference	1995-2014

Source: authors’ elaboration.

The list of offshoring variables available in both versions of the SID database is summarised in Table 9, while Table 10 reports the correlation matrix – i.e. the normalized variance and covariance matrix – of the offshoring variables’ variations computed for all countries over the period and a test on their linear correlation.

⁸ Some studies questioned the reliability of offshoring indicators. For example, Castellani, De Benedictis and Horgos (2013) argue that the offshoring indices usually used may not capture international fragmentation of production but structural change in the economy. Horgos (2009) assesses the design of several offshoring indicators used in analyses targeted to evaluate outsourcing processes’ effects on labour market and argues that empirical results making use of these indicators broadly depend on the particular offshoring index employed.

Table 10. Correlation matrix of offshoring indicators' variations

	Broad offsh. ($\Delta\%$)	Narrow offsh. ($\Delta\%$)	HT offsh. ($\Delta\%$)	LT offsh. ($\Delta\%$)
Broad offsh. ($\Delta\%$)	1			
Narrow offsh. ($\Delta\%$)	0,6882 *	1		
HT offsh. ($\Delta\%$)	0,5868 *	0,5242 *	1	
LT offsh. ($\Delta\%$)	0,7536 *	0,5933 *	0,1359 *	1

Source: Our elaboration on Sectoral Innovation Database.

Note: The table refers to the whole sample: DE, IT, FR, ES, NL, UK; 1996-2014. The percentage variations are computed for the following five periods: 1996-2000, 2000-2003, 2003-2008, 2008-2012, 2012-2014. The star (*) refers to the Pearson correlation coefficient, testing if it is significantly different from zero at a significance level of 1%.

8. Labour market variables

European labour markets have been undergoing major structural transformations over the last several decades. The Sectoral Innovation Database (SID) provides information on the labour market dynamics, including a set of indicators that capture the occupational structure, contractual arrangements and educational attainment at industry level. The primary source of labour market data is the EU Labour Force Survey provided by Eurostat. Table 13 and Table 14 report a list of labour market variables available in the SID Rev.1 and SID Rev.2. In what follows, we describe their main features and the way they have been built to be included in the SID database.

Occupational groups

Job polarisation is one of the key features of the European labour markets. To investigate this trend, we rely on the International Standard Classification of Occupations (ISCO), widely adopted in empirical research. The ISCO classification reflects the nature of the tasks performed and the skill content of the job.

Building on Cirillo (2017), we define four occupational groups - Managers, Clerks, Craft and Manual workers - by aggregating the International Standard Classification of Occupations (ISCO08) 1-digit classes⁹ in the way shown in Table 11. This occupational grouping aims to summarise the hierarchical position of workers, the task content of jobs and wage differences.

⁹ A revision of the International Standard Classification of Occupations (ISCO) took place in 2011, when ISCO-88 was succeeded by ISCO-08, resulting in a break in the occupational series; Germany in 2012 reassigned some ISCO occupations (Eurofound, 2017). To achieve consistency in data for the period of our analysis, we retained the updated classification and estimated 2009 data for occupational groups on the basis of their share in total employment in 2011; for Germany the base year is 2012.

Table 11. The professional groups

Occupational groups	ISCO 1 digit classes
Managers	Managers, senior officials and legislators
	Professionals
	Technicians and associate professionals
Clerks	Clerks
	Service and sales workers
Craft workers	Skilled agricultural and fishery workers
	Craft and related trade workers
Manual workers	Plant and machine operators and assemblers
	Elementary occupations

Source: Cirillo (2017).

Educational attainment

In the SID Rev.2, data on educational attainment are available for three broad educational groups: low, medium and university education. These were constructed by aggregating International Standard Classification of Education (ISCED) as indicated in Table 12.

Table 12: The educational attainment groups

Occupational groups	ISCED
Low	Less than primary education
	Primary education
	Lower secondary education
Medium	Upper secondary education
	Post-secondary non-tertiary education
High	Short-cycle tertiary education
	Bachelor studies
	Master studies
	Doctoral studies

Source: EU Labour Force Survey Database User Guide (2019)

Non-standard forms of work

The deregulation of the labour market in recent decades has led to the diffusion of non-standard forms of employment in European industries. To account for this phenomenon, using the microdata from *EU Labour Force Survey*, we construct a variable *Non-standard work* by cross-tabulating employees on the permanency of the job (permanent and temporary) and by hours worked (full-time and part-time). Variable non-standard work is expressed as a share of full-time temporary, part-time permanent and part-time temporary employees over the total number of employees in the sector. Non-standard jobs are often paid less with respect to their ‘standard’ counterparts. Furthermore, non-standard hires tend to have not only lower wages¹⁰ - namely 20-30% lower than that of standard workers with the full-time permanent contract - but also lower wage growth

¹⁰ In 2012, the wage penalty was the highest for part-time temporary workers. They earned, on average 43% less than standard workers in Italy, 34% and 30% less in the UK and France, respectively (OECD, 2015).

(OECD 2015). Thus, we argue that this variable may be an appropriate indicator of the employment quality in industries as it encompasses both temporary and part-time work.

Unionization

Exploiting the ICTWSS (Version 5.1) database (Visser 2016) we built an industry-level indicator of union density – computed as the share of union membership at the industry level – to assess the role of trade unions, conceived as key actors which are expected to shape the distributive dynamics of sectors. Since union density data are only available at an aggregated level of sectoral classification, we implemented the methodology followed by Guschanski and Onaran (2016, 2017): on the one hand, we linearly interpolate the series between available years; on the other, for certain individual industries we extrapolate missing data computing the union density growth rate based on the data available for the next higher level of aggregation (which may even be country-level union density data whether data at a higher level of disaggregation are not available). For example, we extrapolate data for individual manufacturing sectors using the growth rate of the total manufacturing union density (or, if the latter is not available, we use the country-level union density rate of growth) (see Guschanski and Onaran 2017, p. 11). Unfortunately, such procedure inevitably reduces the inter-industry variability of union density data and questions to some extent its reliability, without allowing to fully account for various economic events or shifts in policy orientation that affect industrial relations and the power balance between capital and labour. However, we argue that the relevance accorded to the union density variable by our empirical analysis suggests its ability in capturing the role of wage bargaining institutions on income distribution dynamics.

Table 13. List of labour market variables in the SID Rev.1

	Label	Expressed as	Availability
Occupational structure (ISCO professional groups)			
Share of Managers	QMAN	Share (%)	1995-2014
Share of Clerks	QCLE	Share (%)	1995-2014
Share of Craft workers	QCWO	Share (%)	1995-2014
Share of Manual workers	QMWO	Share (%)	1995-2014
Non-standard forms of employment			
Stable employees (full-time, permanent contract)	EST	Thousand of employees	1995-2014
Unstable employees (part-time and/or fixed-term contract)	EUN	Thousand of employees	1995-2014
Share of stable employees	QEST	Share (%)	1995-2014
Share of unstable employees	QEUN	Share (%)	1995-2014
Unionization			
Union density	UD	Share (%)	1995-2014

Source: authors' elaboration.

Table 14: List of labour market variables in the SID Rev.2

Label	Code	Unit	Availability
Occupational structure			
Share of Managers	QMANA	Share (%)	2000-2017
Share of Clerks	QCLERK	Share (%)	2000-2017
Share of Craft workers	QCRAFT	Share (%)	2000-2017
Share of Manual workers	QMANU	Share (%)	2000-2017
Managers	VMANA	Annual rate of growth (%)	2000-2017
Clerks	VCLERK	Annual rate of growth (%)	2000-2017
Craft workers	VCRAFT	Annual rate of growth (%)	2000-2017
Manual workers	VMANU	Annual rate of growth (%)	2000-2017
Education			
Share of high education	QEDUHIGH	Share (%)	1995-2017
Share of medium education	QEDUMED	Share (%)	1995-2017
Share of low education	QEDULOW	Share (%)	1995-2017
High education	VHIGH	Annual rate of growth (%)	1995-2017
Medium education	VEDUMED	Annual rate of growth (%)	1995-2017
Low education	VEDULOW	Annual rate of growth (%)	1995-2017
Type of contract			
Share of temporary workers	QTEMP	Share (%)	1995-2017
Share of permanent workers	QPERM	Share (%)	1995-2017
Share of part-time workers	QPART	Share (%)	1995-2017
Share of full-time workers	QFULL	Share (%)	1995-2017
Share of non-standard workers	QNSW	Share (%)	1995-2017
Temporary workers	VTEMP	Annual rate of growth (%)	1995-2017
Permanent workers	VPERM	Annual rate of growth (%)	1995-2017
Part-time workers	VPART	Annual rate of growth (%)	1995-2017
Full-time workers	VFULL	Annual rate of growth (%)	1995-2017
Non-standard workers	VNSW	Annual rate of growth (%)	1995-2017
Unionisation			
Union density	QUNION	Share (%)	1995-2014

Source: authors' elaboration.

Note: All variables are either expressed as shares over the total number of employees in the sector or as compound average annual rates of change.

9. Digital variables

Measuring the diffusion of digital technologies in the economy is an important challenge, considering conceptual problems and data constraints. Building on Calvino et al. (2018) we construct two indicators of digitalization at the industry level: (1) digital inputs - *share of intermediate consumption of ICT goods and services in total intermediate consumption*; (2) ICT investment - *total investment in ICTs per employee*.

The first indicator measures the diffusion of inputs based on ICT goods and services, provided by ICT producing sectors (Manufacture of computer, electronic and optical products; Telecommunications; Computer programming, consultancy, and related activities). We argue that digital inputs have the potential to improve the industries' performance and complement product innovations. Using data from World Input-Output Tables (WIOT), the variable is constructed as a share of intermediate consumption of ICT goods and services over the total intermediate consumption.

$$Digital\ inputs_{ijt}^k = \frac{Intermediate\ consumption_{ijt}^k}{Total\ intermediate\ consumption_{ijt}}$$

$$k \in \{ICT\ producing\ sectors\}$$

where i stands for the industry, j for the country, t for the time, and k for ICT producing sectors.

To measure the ICT capital deepening and the importance of computers, telecommunication networks, software and databases for an industry, we construct a second indicator - ICT investment per employee.

$$Digital\ investment_{ijt}^k = \frac{Gross\ fixed\ capital\ formation_{ijt}^k}{Total\ number\ of\ employees_{ijt}}$$

$$k \in \{Computer\ hardware, communication\ equipment, software\ and\ databases\}$$

where i stands for the industry, j for country and t for time. The ICT investment data was sourced from the EU KLEMS (2019 release), which reports at a more aggregated sectoral level with respect to the SID. To match the two-digits sectoral breakdown available in the SID Rev.2 we had to disaggregate several sectors. Latter was done by imputing missing data points, using time-country-industry-specific weights calculated as follows¹¹:

$$w_{ijk} = \frac{Emp_{ijk}}{\sum_{i=1}^n Emp_{ijk}}$$

where Emp is the number of employees in sector i (e.g. K64 ‘Financial Service Activities’) of country j ; n is the number of sectors included in the EU KLEMS’ k -th sector (e.g. K64, K65 and K66, so that $n=3$); the denominator is the total employment of the EU KLEMS’ k -th sector (e.g. total employment of sector K- ‘Finance, Insurance and Auxiliary activities’) in country j .

The complete list of indicators available in the SID Rev.2 that could be used to proxy the patterns of digitalization at industry level is summarised in Table 15.

¹¹ The procedure was adopted from SID WP 2014.

Table 15. List of ICT variables

Label	Code	Unit	Availability
Investment in ICT			
Real investment in Computing equipment	ICTIT_IT	Thousand euro per employee	1996-2016
Real investment in Telecommunication equipment	ICTIT_CT	Thousand euro per employee	1996-2016
Real investment in ICT tangible assets	ICTIT	Thousand euro per employee	1996-2016
Real investment in Software and databases	ICTII	Thousand euro per employee	1996-2016
Total real investment in ICT	ICTI	Thousand euro per employee	1996-2016
Real investment in ICT tangible assets	ICTIT_GFCF	% of GFCF	1996-2016
Real investment in Software and databases	ICTII_GFCF	% of GFCF	1996-2016
Digital inputs			
Intermediate purchase of ICT goods	ICTCG	% of intermediate consumption	2000-2014
Intermediate purchase of ICT services	ICTCS	% of intermediate consumption	2000-2014
Intermediate purchase of ICT goods and services	ICTC	% of intermediate consumption	2000-2014
Intermediate purchase of ICT goods	ICTCOG	% of output	2000-2014
Intermediate purchase of ICT services	ICTCOS	% of output	2000-2014
Intermediate purchase of ICT goods and services	ICTCO	% of output	2000-2014

Source: authors' elaboration.

10. Time structure of the database and deflation methodology

Time structure of the SID database

The SID allows to account for the different phases of the business cycle, investigating how the relationships among output rates of growth, innovation regimes, demand dynamics and offshoring strategies change during the upswing and downswing periods (Cirillo et al. 2018; Lucchese and Pianta 2012; Guarascio et al. 2015). On the one hand, this perspective links our structural analysis to the dynamics of the economic aggregates; on the other hand, focusing on the role of the business cycle at industry level may allow to better assess the different pace of technological and structural change of the economies.

On this ground, the Schumpeterian theory of the business cycle (Schumpeter 1939) puts major emphasis on the role of investments in technological innovation as the element that governs the succession of development stages of capitalism. According to Schumpeter's vision, the ability and the rent-seeking attitude of entrepreneurs leads them to introduce disruptive innovations which kick off great investment opportunities and lay the foundations for a new phase of development. The introduction of innovations makes it possible to obtain extra-profits which, in turn, are the engine that triggers economic growth as well as further investments by the mass of potential imitators. Once the previously introduced technological innovation has become pervasive, reaching an advanced stage of diffusion, the most intense competition (due to the high number of imitators and the emergence of diminishing returns) tends to reduce monopolistic profits, while the sectors producing innovative products tend to become saturated, thus discouraging further investments. A slow down of demand growth follows, mainly for capital investments, that generates a recession, which may turn into a phase of depression before the growth starts again as a result of a new wave of innovations, bringing about investments as well as new institutional and social challenges.

The Schumpeterian conception of economic development is very far from any view of steady-state growth in equilibrium conditions. On the contrary, technological innovation triggering the development phase is intrinsically unbalancing as it tends to concentrate in time and space. On the one hand, the development of innovative technologies by some companies is followed by irregular processes of imitation, diffusion and adaptation, which in turn tend to generate waves of development that translate into a process of disharmonic and cyclical growth. This means that the changes fostered by innovation may break the existing equilibrium, unbalance the structure of the economic system and give rise to phenomena of cyclical evolution. On the other hand, technological innovation tends to concentrate in some key sectors depending on their knowledge base and the degree of development of the productive forces determined by the historical phase; this dynamics process generates structural asymmetries that result in different growth rates of sectors, leading to the expansion of certain industries to the detriment of others, which instead experience phases of decline.

On this ground, Mensch (1979) argued that firms tend to introduce innovations during depressions since periods of low profitability force them to innovate with the aim to capture growing rents; conversely, during upswing they have relatively lower incentive to innovate since can rely on higher demand for existing products to achieve their profitability targets. On the contrary, Freeman (1974, 1982) and Freeman and Louca (2001) stressed that the uncertain nature of technological change and low opportunities due to weak demand dynamics discourage the introduction of product innovation during the downswing, while in such circumstances innovative efforts aimed at the introduction of new processes associated to production restructuring tend to be carried out; on the other side, during periods of recoveries the expansion of the markets due to a growing demand provides the condition to successfully introduce product innovation to increase market share and gain higher rents.

Moreover, the literature on the global fragmentation of production has shown that offshoring activities, being strongly connected with the dynamics of international trade, are strictly intertwined with business cycles dynamics (Easterly et al. 2000; Burstein et al. 2008; Feenstra 2010). Di Giovanni and Levchenko (2012) performed an industry-level analysis and found that sectors which show a high degree of openness to both intermediate and final goods trade are relatively more volatile, albeit they result less influenced by the dynamics of the domestic economy. Feenstra (2010) discussed the potential interaction among demand shocks, offshoring and business cycle, arguing that increases in demand in the home country (i.e. the one pursuing the offshoring activity) may induce increases in wages that, in turn, foster production offshoring as firm's strategy to reduce labour costs; it follows a reduction of the domestic output, which soften the effects of the original demand expansion.

Building on such approaches, the time structure of the SID was built to reflect the evolution of the business cycle. As a consequence, the SID Rev.1 database is a panel over

five periods covering a time span from 1994 to 2014, while the SID Rev.2 is a panel of six periods covering a time span from 1994 to 2016. In particular, the variables included in the database are calculated as follows:

- *Economic variables* are computed for the periods 1996-2000, 2000-2003, 2003-2008, 2008-2012, 2012-2014 (2012-2015 in the SID Rev.2) as compound annual growth rate, that approximates the difference in logarithmic terms.
- *Demand and offshoring variables* are computed for the periods 1996-2000, 2000-2003, 2003-2008, 2008-2012, 2012-2014. For demand and distributive variables, we compute the compound annual growth rate, that approximates the difference in logarithmic terms; for offshoring indicators we take the simple difference between the value in the last and first year of each period.
- *Innovation variables* are taken from six waves of innovation survey: the first wave (CIS 2) refers to 1994-1996 and is linked to the first period of economic variables; the second wave (CIS 3) spans 1998-2000 and is linked to the second period of economic variables; the third wave (CIS 4) refers to 2002-2004 and is linked to the third period of economic variables; the fourth wave (CIS 7) spans 2008-2010 and is linked to the fourth period of economic variables; the fifth wave (CIS 9) refers to 2012-2014 and is linked to the fifth period of economic variables; the sixth wave (CIS10) refers to 2014-2016.^{12, 13}
- *ICT variables* in levels refer to the first year of the six economic periods, i.e. 1996, 2000, 2004, 2008, 2012, 2014. Instead, the rate of change of ICT investment per employee (e.g. tangible, intangible) is computed as compound annual growth rates over the following periods: 1996-2000, 2000-2004, 2004-2008, 2008-2012, 2012-2014.
- *Union density* refers to the first year of each of the five economic periods, i.e. 1996, 2000, 2003, 2008, 2012, and is computed as the union membership rate at industry level; the rate of change is computed by taking the simple difference between the value in the last and first year of the following periods: 1996-2000, 2000-2003, 2003-2008, 2008-2012, 2012-2014
- *Labour market variables*, expressed as shares, refer to the first year of each of the six periods, i.e. 1996, 2000, 2003, 2008, 2012, 2015; while, variables expressed

¹² The variable related to the expenditure for new machinery and equipment contains missing values for the first two CIS waves by construction. However, missing values are homogeneously distributed across countries in service industries. Unfortunately, the variable related to the turnover due to innovation contains, by construction, missing values for Germany and the Netherlands in the second CIS wave and for France in the third CIS wave.

¹³ The temporal structure of the database is firstly due to the frequency according to which Eurostat collects the innovation surveys and makes them available. Secondly, the surveys' innovation-related questions are partially changed over the time, forcing us to select consistently the CIS containing the variables of our interest. Finally, we matched the economic and innovation variables so that the latter are lagged relative to the former, bearing in mind the time needed by technological efforts to display their effects.

as compound annual growth rates are computed for the following periods: 1996-2000, 2000-2003, 2003-2008, 2008-2012, 2012-2015 and 2015-2017.

The periodization of the previous version of the SID database, covering the time span 1994-2010, is presented in Table 16, while the time structures of the SID Rev.1 and the SID Rev.2 databases are summarized in Table 17 and Table 18 respectively.

Table 16. Time structure of the previous version of the SID Rev.1 (1994-2010)

	<i>CIS 2</i>	<i>CIS 3</i>	<i>CIS 4</i>	<i>CIS 6</i>
CIS waves	1994-1996	1998-2000	2002-2004	2006-2008
Economic variables	1996-2000	2000-2003	2003-2007	2007-2010
	<i>First period</i>	<i>Second period</i>	<i>Third period</i>	<i>Fourth period</i>

Source: authors' elaboration.

Table 17. Time structure of the current SID Rev.1 database (1994-2014)

	<i>CIS 2</i>	<i>CIS 3</i>	<i>CIS 4</i>	<i>CIS 7</i>	<i>CIS 9</i>
CIS waves	1994-1996	1998-2000	2002-2004	2008-2010	2012-2014
Economic variables	1996-2000	2000-2003	2003-2008	2008-2012	2012-2014
	<i>First period</i>	<i>Second period</i>	<i>Third period</i>	<i>Fourth period</i>	<i>Fifth period</i>

Source: authors' elaboration.

Table 18: Time structure of the current SID Rev.2 database (1994-2016)

	<i>CIS 2</i>	<i>CIS 3</i>	<i>CIS 4</i>	<i>CIS 7</i>	<i>CIS 9</i>	<i>CIS 10</i>
CIS variables	1994-1996	1998-2000	2002-2004	2008-2010	2012-2014	2014-2016
ICT investment	1996	2000	2004	2008	2012	2014
ICT intermediate inputs	x	2000	2004	2008	2012	2014
Offshoring	1996-2000	2000-2003	2003-2008	2008-2012	2012-2014	x
Unionization	1996-2000	2000-2003	2003-2008	2008-2012	2012-2014	x
Labour market variables						
*Contract type	1996-2000	2000-2003	2003-2008	2009-2012	2012-2015	2015-2017
*ISCO	x	2000-2003	2003-2008	2008-2010	2012-2015	2015-2017
*Education	1996-2000	2000-2003	2003-2008	2008-2012	2012-2015	2015-2017
Economic variables	1996-2000	2000-2003	2003-2008	2008-2012	2012-2015	x
	<i>First period</i>	<i>Second period</i>	<i>Third period</i>	<i>Fourth period</i>	<i>Fifth period</i>	<i>Sixth period</i>

Source: authors' elaboration.

Deflation methodology

All monetary variables included in the SID database are expressed in euros and have been adjusted for the evolution of prices (the base year is 2000). In particular, we deflated the variables related to the expenditure in research and development, expenditure in new machinery and equipment, gross fixed capital formation, gross operating surplus (profits), compensation of employees (wages) and imports using the aggregate value added deflator provided by OECD-STAN. Instead, the variables related to value added, gross output and exports have been deflated using the sectoral value added deflators provided by WIOD-SEA (SID Rev.1) and OECD-STAN (SID Rev.2).¹⁴

¹⁴ The other monetary variables included in the SID database, e.g. labour compensation per employee and labour productivity, have been consequently built using data in real terms.

It should also be noted that, concerning the NACE Rev. 1 version of the SID database, sectors 30 (Office, accounting & computing machinery) and 66 (Insurance and Pension Funding, except compulsory social security) have been deflated considering the price index of the aggregate electrical and optical sector (30-33 sectors) and financial intermediation (65-67) respectively, in order to reduce the effects of hedonic prices in STAN. Similarly, in the SID Rev.2, to lessen the effect of hedonic prices and oil price shocks, in exceptional cases, we used one-digit sectoral deflators. In particular, Financial and insurance activities (K) deflator has been used to deflate value added, gross output and productivity of Financial service activities (K64), Insurance, reinsurance and pension funding (K65) and Activities auxiliary to financial service and insurance activities (K66), while Transportation and storage (H) deflator has been used for Water transport (H50) and Air transport (H51) sectors.

Variables that we built exploiting the World Input-Output Tables (which are expressed in millions of US\$) have been firstly deflated at 2000 level of prices and then converted in euros using the exchange rates provided by WIOD, except for the United Kingdom. For this country, the standard procedure that we followed is such that after having deflated at 2000 price level we converted data in pounds (when the source is WIOD-SEA this passage was not necessary, as data in WIOD-SEA are already expressed in local currency); then, we converted pounds to euros using the exchange rate expressed in PPP provided by Stapel et al. (2004, p. 5).

11. The Revised Pavitt Taxonomy

Pavitt (1984) focused on the structure of the markets and on the nature, sources and appropriability of innovation to conceptualize the existence of four different technology-based classes, according to which classify manufacturing industries.

Building on the SID database, Bogliacino and Pianta (2010, 2016) investigated the relationships between innovation patterns and economic performance of service industries and provided a Revised Pavitt Taxonomy which extends the original Pavitt classification to the latter sectors. Here we report a brief description of the four classes of industries classified according to the Revised Pavitt Taxonomy.

- i. Science-Based industries (SB) include sectors where innovation is based on advances in science and R&D (such as the pharmaceuticals, electronics, computer services) where research laboratories are important, leading to intense product innovation and a high propensity to patent.
- ii. Specialised Supplier industries (SS) include the sectors producing machinery and equipment; their products are new processes for other industries. R&D is present but an important innovative input comes from tacit knowledge and design skills embodied in the labour force. Average firm size is small and innovation is carried out in close relation with customers.

- iii. Scale and Information Intensive industries (SI) include sectors (such as the automotive sector and financial services) characterized by large economies of scale and oligopolistic markets where technological change is usually incremental. New processes (often related to information technology) shape the organisation of production and coexist with new product development.
- iv. Supplier Dominated industries (SD) include traditional sectors (such as food, textile, retail services) where internal innovative activities are less relevant, small firms are prevalent and technological change is mainly introduced through the inputs and machinery provided by suppliers from other industries. Firms in this group do not carry out much R&D or other innovative activities.

The list of sectors grouped according to the Revised Pavitt Taxonomy is provided in Table 19 (classified in NACE Rev. 1) and in Table 20 (classified in NACE Rev. 2).

Table 19. The Revised Pavitt Taxonomy (NACE Rev. 1 industry classification)

List of Sectors	NACE Rev. 1 codes
SCIENCE BASED	
Chemicals	24
Office machinery	30
Manufacture of radio, television and communication equipment and apparatus	32
Manufacture of medical, precision and optical instruments, watches and clocks	33
Communications	64
Computer and related activities	72
Research and development	73
SPECIALISED SUPPLIERS	
Mechanical engineering	29
Manufacture of electrical machinery and apparatus n.e.c.	31
Manufacture of other transport equipment	35
Real estate activities	70
Renting of machinery and equipment	71
Other business activities	74
SCALE & INFORMATION INTENSIVE	
Pulp, paper & paper products	21
Printing & publishing	22
Mineral oil refining, coke & nuclear fuel	23
Rubber & plastics	25
Non-metallic mineral products	26
Basic metals	27
Motor vehicles	34
Financial intermediation, except insurance and pension funding	65
Insurance and pension funding, except compulsory social security	66
Activities auxiliary to financial intermediation	67
SUPPLIER DOMINATED	
Food, drink & tobacco	15-16
Textiles	17
Clothing	18
Leather and footwear	19
Wood & products of wood and cork	20
Fabricated metal products	28
Furniture, miscellaneous manufacturing; recycling	36-37
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	50
Wholesale trade and commission trade, except of motor vehicles and motorcycles	51
Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	52
Hotels & catering	55
Inland transport	60
Water transport	61
Air transport	62
Supporting and auxiliary transport activities; activities of travel agencies	63

Source: Bogliacino and Pianta (2016, p. 157)

Table 20. The Revised Pavitt Taxonomy (NACE Rev. 2 industry classification)

List of Sectors	NACE Rev. 2 codes
SCIENCE BASED	
Manufacture of chemicals and chemical products	C20
Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21
Manufacture of computer, electronic and optical products	C26
Telecommunications	J61
Computer programming, consultancy and related activities; information service activities	J62-J63
Scientific research and development	M72
SPECIALISED SUPPLIERS	
Manufacture of electrical equipment	C27
Manufacture of machinery and equipment n.e.c.	C28
Manufacture of other transport equipment	C30
Repair and installation of machinery and equipment	C33
Real estate activities	L68
Legal and accounting activities; management consultancy activities	M69-M70
Architectural and engineering activities; technical testing and analysis	M71
Advertising and market research	M73
Other professional, scientific and technical activities; veterinary activities	M74-M75
SCALE AND INFORMATION INTENSIVE	
Manufacture of paper and paper products	C17
Printing and reproduction of recorded media	C18
Manufacture of rubber and plastic products	C22
Manufacture of other non-metallic mineral products	C23
Manufacture of basic metals	C24
Manufacture of motor vehicles, trailers and semi-trailers	C29
Publishing activities	J58
Audiovisual and broadcasting activities	J59-J60
Financial service activities, except insurance and pension funding	K64
Insurance, reinsurance and pension funding, except compulsory social security	K65
Activities auxiliary to financial services and insurance activities	K66
SUPPLIER DOMINATED	
Manufacture of food products, beverages and tobacco products	C10-C12
Manufacture of textiles, wearing apparel and leather products	C13-C15
Manufacture of wood and of products of wood and cork, except furniture	C16
Manufacture of fabricated metal products, except machinery and equipment	C25
Manufacture of furniture; other manufacturing	C31-C32
Wholesale and retail trade and repair of motor vehicles and motorcycles	G45
Wholesale trade, except of motor vehicles and motorcycles	G46
Retail trade, except of motor vehicles and motorcycles	G47
Land transport and transport via pipelines	H49
Water transport	H50
Air transport	H51
Warehousing and support activities for transportation	H52
Postal and courier activities	H53
Accommodation and food service activities	I55-I56
Administrative and support service activities	N

Source: authors' elaboration.

12. Research based on the Sectoral Innovation Database

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