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From Low-Tech to High-Skill? Innovation System-related-Dynamics in Italy's and Portugal's C&T-Industry.

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Abstract

At least since the early 1990s Europe's national clothing and textile (C&T)-industries have faced an enormous restructuring process, which has been driven *inter alia* by significant changes in the institutional environment (i.e. assignment of the WTO-treaty in 1994). This restructuring went hand in hand with sluggish development. Policy recommendations of the European Commission to stabilise development and increase competitiveness in Europe's national C&T-industries addressed national innovation systems, striving so for a technological breakthrough and a higher competence level of the working force in C&T-production. Focusing on two major European C&T-producing countries – Italy and Portugal – the main purpose of this paper is to explore two types of innovation system-related-dynamics prevailing in the period from 1995 until 2007. To this end, we adopt a meso-macro perspective and figure out whether 'learning' through inter- and intra-industry interaction has unfolded first, in skills-upgrading and second, in changes in average production processes in these two countries' C&T-industries. To embed these aspects of their national innovation systems within a production-oriented framework, we focus on C\&T-employment dynamics, distinguishing also between different skill-types.

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From Low-Tech to High-Skill?

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27th October 2015

Abstract

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Keywords: national innovation system, product-embodied labour flows, skills-upgrading, process innovations, input-output analysis

1 Introduction

According to the OECD-technology intensity classification, low-tech industries are characterised by a low R&D-intensity and a lack of innovative potential. Notwithstanding this

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presumably low innovative potential, Hirsch-Kreinsen et al. (2003) as well as Von Tunzelmann and Acha (2005) show that low-tech industries in developed countries have a strong impact on economic growth in terms of their contribution to value added creation and employment.

Focusing on the clothing and textile (C&T-)industry, as one example which is usually classified as a low-tech industry, this in Europe at least since the 1990s has undergone an enormous restructuring process, caused *inter alia* by institutional changes targeted towards international trade liberalisation. Probably one of the most far-reaching changes in the institutional environment related to Europe's national C&T-industries was the replacement of the 1974-Multifibre Agreement by the WTO Agreement on Textile and Clothing at the beginning of 1995. This was accompanied by a 10-year transition phase, within which a step-by-step elimination of trade restrictions until a total expulsion of protection measures by the end of 2004 took place. Some years after the transition phase, in 2008, import quota were partly reintroduced, since in developed countries value added creation and employment in C&T-production came heavily under pressure (Adhikari and Yamamoto, 2007).

Facing the 2005-challenge, at least since the 2000s the European Union has launched a set of initiatives, targeted towards stabilising development in Europe's national C&T-industries and stimulating their competitiveness. Among them was the High Level Group which placed in particular a *higher qualification of the working force* as well as a *technological breakthrough* in C&T-production on the forefront of its agenda (European Commission, 2004a,b). Keeping the two objectives of the High Level Group in mind, these are exactly functions, which are attributed to a national innovation system as Metcalfe's (1994: 940) definition reflects: 'It is a set of institutions to create, store and transfer the knowledge, skills and artifacts which define technological opportunities.' In other words, national innovation systems were addressed in the European Commission's policy recommendations to sustain an even future development in Europe's national C&T-industries.

As two major European C&T-producing countries we identify Italy and Portugal, since at the beginning of the transition phase, in 1995, more than 36.3% of value added creation and more than 40% of hours worked in the EU-15 C&T-industry took place within the two countries' C&T-industries (Timmer et al., 2015). Due to the before-mentioned institutional changes, Italy's and Portugal's C&T-industries faced an enormous restructuring process manifesting in increased international competition (in particular from low-wage countries such as Bangladesh, China and India) as well as sluggish output, value added and employment growth, as discussed in more detail in Schütz and Palan (2015). For Italy and Portugal, the outcomes of objectives set by the High Level Group were later on summarised in a range of firm-level reports by the European Commission. According to Rosendo and Scheffer (2012), for Italy's C&T-industry success stories centred around a range of product and process innovations (e.g. Digital Printing or Mass-Customization) and Portugal benefited for instance, from increased process efficiency, shorter lead times and an upgrading of skills of the working force. Evaluating these outcomes, in both countries especially interaction of C&T-producing firms with their suppliers and users was identified as decisive for these gradual learning processes. Edquist and Johnson (2012[1997]: 42, italics added) remark on this interaction aspect in the following way: '[I]nnovations are looked upon mainly as the result of *interactive learning processes*. Through interactions in the economy different pieces of knowledge become combined in new ways or new knowledge is created and, sometimes, this results in new processes or products.'

Leaving the micro-level perspective and adopting instead a meso-macro perspective, we set the research focus in our analysis on the industry-linkage structure in which both countries' C&T-industries are embedded. The main purpose of this paper is to explore two types of innovation system-related-dynamics prevailing during the transition phase and some years after. With this study we seek to contribute to a better understanding of the evolution of the C&T-industry in both countries in light of the experienced restructuring. We investigate whether 'learning' through inter- and intra-industry interaction has unfolded first, in skills-upgrading and a different qualitative composition of the direct and indirect labour content of C&T-production and second, in changes in average production processes. To trace the latter aspect, we analyse how technological change impacts on C&T-employment growth in both countries and for studying the first aspect, we stick to dynamics in C&T-employment and distinguish between different skill-types. Hence, labour of different quality types is considered a convenient variable for our study, since C&T-production is typically labour-intensive and employment dynamics are considered to reflect appropriately the overall changes in the two C&T-industries. Approaching the research question from a meso-macro perspective, this allows us capturing the evolution of the existing industry-linkage structure, as a concatenation between their innovation and production systems. We investigate the period from 1995 to 2007 and adopt a comparative-static approach. Concerning the method used, the analytical framework relies on (1) the concept of product-embodied labour flows and (2) structural decomposition analysis (SDA). Furthermore, we take the low-tech industries as a benchmark sector in order to reconcile our empirical results.

The paper proceeds as follows: Section 2 provides a short discussion on the literature background of this study. Based on this, in Section 3 the modelling framework at hand is developed and furthermore, an overview on data handling is given. In Section 4 empirical results are reported. Finally, Section 5 concludes.

2 The Concatenation between Innovation and Production

This paper builds on two different strands of literature. The first one is rooted in the innovation system framework, whereas the second one concerns more the methodological background of this study and is embedded in the literature, which makes use of input-output (I/O-)analysis for exploring technological change or more broadly, different aspects related to the innovation process.

A preliminary question which might be raised, is, how a theoretical framework which largely builds on evolutionary economic ideas such as the innovation system framework can be combined with a method which is based on the 'equilibrium-assumption' (i.e. I/O-analysis). There are basically two arguments, which backbone our approach of combining these, at a first glance, very diverse strands of literature. First of all, in both of them neither production, which in an evolutionary sense can be deemed as 'ways of doing things', nor innovation, as 'ways of doing things differently' (Nelson and Winter, 1982), occur in isolation but instead are understood as *concatenated processes*. The second argument, which pertains more to the nature of the production and innovation process is that both of them are *interactive* ones.

In both strands of literature these arguments find general approval: Referring to an early discussion on the concatenation between production and innovation, Andersen (2010[1992]: 70–71) addressed innovation systems by focusing on the existing production-and-linkage structure in an economic system. In that context he advocated that 'most of what is normally classified as 'innovation' is closely related to existing products and processes. We find first of all that new possibilities are often discovered as more or less unconscious by-products of production and sales activities. Second, more ambitious and conscious searching for and learning about new products and processes quite often start with the problem of existing products and processes [...] Third, in many simple and subtle ways the existing traditions influence the criteria by means of which new ideas are judged.'

Hence, according to him a crucial aspect for exploring innovation systems, is that innovation is a process of continuity and involves the 'transformation' of routine activities into new, non-routine ones, which is a strong evolutionary argument. As an I/O-table reflects the 'production-and-linkage' structure at a meso-macro level at a particular point in time, intertemporal changes in the former can be deemed as the outcomes of the evolutionary mechanism of 'interactive learning'. In other words, changes in the web of linkages as mapped by I/O-tables in different periods, pertain to the transformation of routine activities into new, non-routine ones.[1] Following this line of argument, the central mechanism which is thus binding 'ways of doing things' and 'ways of doing things differently' is *learning*. The recognition of 'learning' as a diversified phenomenon and its importance for economic change dates at least back to Arrow (1962) and Rosenberg (1982). With regard to the study of innovation systems, learning is understood as an interactive mechanism and it perceives of a distinct path-dependency, cumulative nature and is embedded into a specific economic, cultural and institutional environment (Lundvall, 2010[1992]).

But how is learning now accounted for in the research context of this paper? First of all, learning is a continuous mechanism and requires adopting an intertemporal perspective. To satisfy this requirement, we take a comparative-static view. Given that, in our research context learning activities unfold in two different ways: The first concerns changes in the qualitative composition of labour embodied in a specific product over time (i.e. skills-upgrading), as this reflects a different combination of existing and/or new knowledge or in other words, the building up of new or different competencies of the working force. The

[1] This argument is based on the assumption that there are no 'radical' innovations, which would lead to a complete change in the underlying I/O-table.

second one pertains to the consequences of learning as manifesting in process innovations, and hence, in new or changed methods of production.

To embed the first channel of learning into our analysis we make use of the concept of *product-embodied resource flows*. Different from the disembodied nature of innovation, in exploring various aspects of the innovation process by making use of this concept, it is assumed that learning and innovation are of an embodied character. This means that new knowledge spreads through an economic system over the existing linkage structure and is embodied in the transfer of commodities between firms, or on a meso-macro level between industries or sectors. These linkages act thus as carriers for these new or improved artifacts (Leoncini and Montresor, 2003). Building on this 'embodiment hypothesis', there has been a large body of literature which make use of e.g. research and development (R&D) expenditure to study *technology flows* (Papaconstantinou et al., 1998), *innovation flows* in vertically integrated industries (Leoncini et al., 1996; Leoncini and Montresor, 2003) or *knowledge flows* (Hauknes and Knell, 2009). Initially, the idea to combine I/O-tables with innovation indicators such as R&D data or patent data was developed by Schmookler (1966) and Terleckyj (1974).

Our approach is similar to these works only with respect to the adopted method, but we do not take R&D expenditure or patent data to study aspects of interactive learning. Instead we follow Kalmbach and Kurz (1985), who apart from studying R&D flows used labour flows measured by the amount of embodied R&D personnel to investigate the technological content of a specific commodity. Different from their research purpose, we are interested in the dynamics of the 'full' skill-content of a specific commodity, which involves not only R&D personnel but requires taking account of labour of various different quality types. Hence, in this respect we are, from a conceptual viewpoint, closer to e.g. Los et al. (2014) and Foster et al. (2012), who study changes in the skill-structure of labour demand caused by institutional changes, technological change and globalisation.

Regarding the second channel of learning, we study the impact of the diffusion of process innovations on employment growth by means of SDA. Process innovations in that context are understood as changes in the average 'production recipe', leading to different factor proportions (i.e. technology coefficients) in the intermediate transaction matrix of an I/O-table. Hence, learning in this context unfolds in a different quantitative and/or qualitative combination of intermediate inputs.[2] SDA has been a prominent tool in I/O-analysis to break down the changes in one variable into its components. For instance, Dietzenbacher and Los (1998), Dietzenbacher et al. (2000) and more recently, Yang and Lahr (2010) as well as Strohmaier and Rainer (2013) apply SDA to decompose changes in labour productivity growth in its partial effects. Different from them, we do not focus on the impact of technological change on labour productivity growth. Nevertheless we take account of labour productivity growth as well, as discussed in more detail in the next Section 3.

[2] We are well aware of the fact, that process innovations involve not only changes in circulating but also in fixed capital, but due to data limitation, we cannot take account of fixed capital in this study.

3 Method and Data

3.1 A Subsystem Perspective on Product-Embodied Labour Flows

For k countries and for n industries, matrix $Z_t^{k,D}$ of dimension $n \times n$ at time t includes domestic intermediate transaction flows and thus, one element $z_{t,ij}^{k,D}$ corresponds to the value of intermediate transactions between any pair of industries $i, j = 1, \ldots, n$. Furthermore, the $n \times 1$ column vectors x_t^k and y_t^k denote the gross output vector and the vector of final demand[3] of country k at time t. The matrix of domestic input coefficients $A_t^{k,D}$ of dimension $n \times n$ is given by $Z_t^{k,D}(diag(x_t^k))^{-1}$, where the symbol $diag(\cdot)$; is used to the denote the diagonalisation of a vector. Then, as a starting point for our analysis the following open I/O-system is used:

$$x_t^k = A_t^{k,D} x_t^k + y_t^k \tag{1}$$

The solution of equation (1) is given by $(\mathbb{I} - A_t^{k,D})^{-1} y_t^k = x_t^k$, where $(\mathbb{I} - A_t^{k,D})^{-1}$ is the domestic Leontief-Inverse $\mathbb{L}_t^k$ of country k at time t and $\mathbb{I}$ denotes an identity matrix of the same size as matrix $A_t^{k,D}$. In a further step, the open I/O-system is transformed into vertically integrated industries (i.e. subsystems):

$$S_t^k = (diag(x_t^k))^{-1} \mathbb{L}_t^k diag(y_t^k) \tag{2}$$

One element $s_{t,ij}^k$ of matrix S_t^k gives the share of industry i's gross output which is required both directly and indirectly to satisfy subsystem j's final demand at time t. Thus, matrix S_t^k shares the property that if working on the complete final demand vector – as it is the case in this paper – each row adds up to 1 (Momigliano and Siniscalco, 1982). On the basis of equation (2), labour of different quality types is introduced into the system as follows:

$$L_t^{k,s} = diag(\bar{l}_t^{k,s}) S_t^k \tag{3}$$

In equation (3) $\bar{l}_t^{k,s}$ is an $n \times 1$ vector containing industry labour requirements in country k of skill-type $s =$ low (l), medium (m) and high (h) at time t. A generic element $l_{t,ij}^{k,s}$ of matrix $L_t^{k,s}$ gives the direct and indirect labour of a particular skill-type, which subsystem j requires from industry i to satisfy its own final demand.[4] Accounting for both direct and indirect labour flows proves beneficial, since it provides a thorough picture on the 'true' skill-content of each final demand category.

Equation (3) is the starting point for deriving a first indicator showing the qualitative composition of labour inputs in vertically integrated industries in a particular period. Therefore vectors of column-sums $c_t^{k,s}$ for each single matrix $L_t^{k,s}$ are built. Furthermore, let $c_t^k = \sum_s c_t^{k,s}$ be a vector of dimension $1 \times n$, whose elements correspond to total embodied hours worked in each vertically integrated industry j of country k at time t. Then, the row

[3]Final demand includes domestic final consumption by households, by non-profit organisations and by government, gross fixed capital formation, changes in inventories as well as exports.

[4]Note that matrix L_t^k, containing *total* labour requirements – irrespective of the skill-type – in each vertically integrated industry at time t, is obtained by simply summing over s: $L_t^k = \sum_s L_t^{k,s}$.

vectors $\psi_t^{k,s}$ of dimension $1 \times n$, containing skill-shares of subsystems are obtained through elementwise division:

$$\psi_t^{k,s} = c_t^{k,s} \oslash c_t^k \tag{4}$$

In comparing changes of different skill-shares of a single vertically integrated industry j of country k over time, this provides information about whether skills-upgrading took place. Hence, shifts in skill-shares signalise a change in the qualitative composition of a subsystem's final demand labour content, in the sense that its production got either more or less low-skilled, medium-skilled or high-skilled intensive.

To get an idea of the extent of inter-industry interaction with upstream producers of a single vertically integrated industry j, the degree of vertical integration is studied. Using again equation (3) as a starting point, for a cross-country comparison this needs to be normalised such as to make it invariant to scale effects (Montresor and Vittucci Marzetti, 2009):

$$\bar{L}_t^{k,s} = L_t^{k,s}\big(diag(e^T L_t^{k,s})\big)^{-1} \tag{5}$$

In equation (5), e denotes the summation vector of dimension $n \times 1$. Normalisation proceeds along columns and each coefficient of the respective matrix $L_t^{k,s}$ is divided by its corresponding column-sum. Comparing elements on the main diagonal with the column-sum of elements off the main diagonal, we obtain information about the intensity of backward linkages of each vertically integrated industry in terms of product-embodied heterogeneous labour flows. If skills-upgrading took place, then an intertemporal comparison of the degree of vertical integration provides insight into whether single subsystems built more on external (inter-industry) or internal (intra-industry) sources of learning.

Another interesting issue is to know about whether inter-industry interaction between the C&T-industry and upstream producers was rather dispersed or otherwise, concentrated to only few others. Therefore we calculate subsystem-specific Gini-Indexes $G_{t,j}^{k,s}$. As a preparatory step, each column j of matrix $\bar{L}_t^{k,s}$ is reduced by the element $\bar{l}_{t,ij}^{k,s}$ for which $i = j$. After that the n column vectors of dimension $(n-1) \times 1$ are normalised along column-sums once again, and elements $\tilde{l}_{t,i}^{k,s}$ of each column vector so-adopted are sorted in ascending order. Then the Gini-Index $G_{t,j}^{k,s}$ for a single vertically integrated industry j is:

$$G_{t,j}^{k,s} = \frac{2\sum_i i\tilde{l}_{t,i}^{k,s} - n}{(n-1)} \tag{6}$$

Each $G_{t,j}^{k,s} \in [0,1]$ and the higher its value, the more unevenly distributed are backward linkages of a single vertically integrated industry j. Thus for a $G_{t,j}^{k,s}$ near 1, this means that subsystem j only shares few strong linkages with upstream producers, whereas for $G_{t,j}^{k,s}$ near 0, interaction with upstream producers is rather dispersed and subsystem j interacts with many other industries upstream in a rather equalised way.

3.2 Structural Decomposition of Employment Growth

In a final step we apply SDA in a discrete comparative-static framework. Setting different skill-types aside for a moment, to start with we take matrix L_t^k from equation (3), which is obtained through summing over skill-types s. Let then $g_{t-1,t}^{k,L}$ be an $n \times 1$-vector containing employment growth in each vertically integrated industry for country k between periods $t-1$ and t, defined as:

$$g_{t-1,t}^{k,L} \equiv \frac{(L_t^k - L_{t-1}^k)e}{L_{t-1}^k e} = \frac{\big(diag(\bar{l}_t^k)S_t^k - diag(\bar{l}_{t-1}^k)S_{t-1}^k\big)e}{L_{t-1}^k e} \tag{7}$$

Substituting the right-hand side of equation (2) for $S_{\cdot}^k$, the growth rate of employment can be also written as:

$$\begin{aligned} g_{t-1,t}^{k,L} = diag\bigg(\frac{1}{L_{t-1}^k e}\bigg)\bigg(&\big(diag(\bar{l}_t^k)(diag(x_t^k))^{-1}\mathbb{L}_t^k diag(y_t^k) - \\ & diag(\bar{l}_{t-1}^k)(diag(x_{t-1}^k))^{-1}\mathbb{L}_{t-1}^k diag(y_{t-1}^k)\big)e\bigg) \end{aligned} \tag{8}$$

Equation (8) lies at the core of our SDA and is used as a starting point for decomposing into partial effects. In general, structural decompositions are not unique and there are different ways to decompose equation (8). The number of alternative decompositions increases in the number n of partial effects distinguished with a factor $n!$. Following Dietzenbacher and Los (1998) as well as Dietzenbacher et al. (2000), we use a polar decomposition to break down changes in $g_{t-1,t}^{k,L}$ in each country into its partial effects.[5] In our decomposition, elements of $g_{t-1,t}^{k,L}$ can change due to the following effects:

- In equation (8), $\lambda_{\cdot}^k \equiv (diag(\bar{l}_{\cdot}^k)(diag(x_{\cdot}^k))^{-1})e$ corresponds to the $n \times 1$-vector of total labour coefficients $\lambda_{\cdot}^k$ in each vertically integrated industry, containing hours worked per unit of gross output. Hence, changes in labour coefficients (i.e. in inverse labour productivity) between two periods are given by $\Delta\lambda^k \equiv \lambda_t^k - \lambda_{t-1}^k$. This we further decompose into changes in skill-type specific labour coefficients $\Delta\lambda^{k,s}$, with $s = l, m, h$.

- Changes in the Leontief-Inverse: $\Delta\mathbb{L}^k \equiv \mathbb{L}_t^k - \mathbb{L}_{t-1}^k$, which show changes in the overall industry-linkage structure; this is extended to differentiate between, first, changes in average production technology and, second, substitution of imported inputs for domestic inputs.

- Final demand changes, determined by $\Delta y^k \equiv y_t^k - y_{t-1}^k$.

The decomposition is described in more detail in Appendix A.

[5] If decomposition grasps changes in a variable between two periods $t-1$ and t, the idea of 'polar decomposition' is to index in a first polar decomposition all variables through by the starting period $t-1$ and in a second polar decomposition all variables are indexed through by the end period t, except for the variable to which the partial effect refers. In the final decomposition, this involves taking the average of the two polar decompositions.

3.3 Data Preparation

In this paper most of the raw data was used from the World Input-Output database (WIOD) (Timmer, 2012; Timmer et al., 2015). Annual national I/O-tables published by the WIOD for Italy and Portugal – in which separate import matrices are included – range from 1995 to 2011. National I/O-tables are expressed in current prices of million US-$ and the classification is based on ISIC Rev. 3, including 35 industries. Since first, the socio-economic accounts 2012-version (Erumban et al., 2012) from which employment on an industry-level was taken (measured in hours worked by persons engaged) only covers the period from 1995 until 2009; and second, for Portugal the employment share of each manufacturing industry in total manufacturing is constant from 2007 until 2009, finally the period from 1995 until 2007 was taken for the analysis even if it would have been beneficial to have access to data ranging to more years after the transition phase.

To make I/O-tables comparable across time, they were deflated in a row-wise procedure. Therefore, price indexes on an industry-level, where 1995 = 100 for (1) intermediate demand and (2) gross output were used.[6] To maintain equality between row- and column-sums in the deflated national I/O-tables, real final demand was taken as the difference between real gross output and real intermediate demand.

Regarding the variable hours worked, some further preparatory work was done. The WIOD publishes hours worked for three different skill-types – low, medium and high – on an industry-level for countries included in the sample.[7] Yet, for Portugal shares of each skill-type in total hours worked are constant for the whole manufacturing sector. Since this would constitute a severe problem to the empirical part of our analysis we used additional data from the EU-Labour Force Survey (2014): labour demand on an ISIC Rev. 3 industry-level of low, medium and high skill-type expressed in 1000 engaged persons. After calculating skill-shares in total engaged persons based on this dataset, these shares were taken to recalculate hours worked of different skill-types in each industry from the WIOD-dataset. In doing so, we implicitly assume that each person engaged, independent of her skill-level, works the same number of hours. This indeed is somewhat problematic, but necessary vis-à-vis the available data.

[6]Since the focus in this paper is only on subsystems and as shown by Rampa (1982), systems of vertically integrated industries are invariant to relative price changes we refrained from using chained price indexes to deflate our data but instead used constant base year price indexes.

[7]The distinction between the three skill-levels is based on ISCED97 (Erumban et al., 2012). As there are large differences between national education systems it can be very difficult to compare them internationally. Therefore, ISCED97 (International Standard Classification of Education) was developed in order to make national education systems more comparable across countries. The ISCED is based on uniform and internationally agreed definitions. See UNESCO Institute for Statistics (2014).

4 Empirical Results

4.1 Descriptive Analysis

To get a rough idea of employment dynamics in Italy's and Portugal's C&T-industries during the observation period, in this section some descriptive statistics are discussed.[8] At this point we refer only to *direct* hours worked and thus, only a fraction of the 'true' labour content of C&T-production is accounted for.

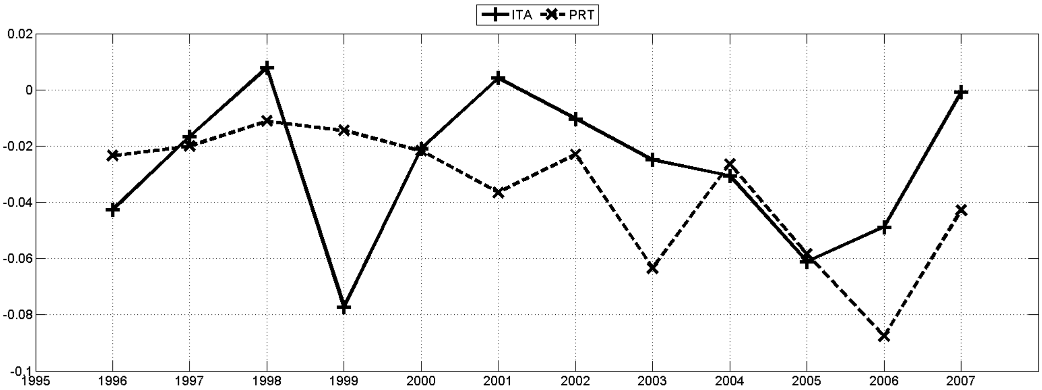

Figure 1: Employment growth rate in the C&T-industries of Italy (solid line) and Portugal (dashed line), 1995–2007.
Data Source: Timmer et al. (2015). Author's own calculations.

As can be seen from Figure 1, both countries experienced negative employment growth phases in all years except two. On an annual average, hours worked in the C&T-industry decreased by 2.7% in Italy and by 3.6% in Portugal. This signalises that the slump in employment in Portugal was more persistent than in Italy. As regards our benchmark (Appendix B, Table B5), in both countries employment – with a few exceptions – decreased as well from 1995 to 2007. Yet, in both countries annual fluctuations in employment in their C&T-industries were more pronounced than in their low-tech sectors. Thus, at least from a production-oriented point of view, employment in the C&T-industries of the two countries came under pressure and the restructuring process went hand in hand with a continuous reduction in hours worked.

Sticking next to the qualitative composition of hours worked directly in the two C&T-industries (see Figure 2), in both countries the largest fraction of employment was of low-skilled type throughout the observation period, while medium-skilled hours worked in the two C&T- industries accounted for the 2nd largest share and high-skilled for the smallest. As illustrated in the upper panel of Figure 2, in Italy the share of low-skilled labour decreased throughout the observation period, while the shares of medium-skilled and high skilled-labour accelerated year after year.

For Portugal, however, different trends were observed (Figure 2, lower panel). While the

[8]For a more detailed discussion on the development of other economic variables than employment in the C&T-industries of Italy and Portugal, the reader is referred to Chapter ??.

share of low-skilled labour increased from 1995 until 1999, during the remaining years of the observation period it continuously declined and vice versa, the share of medium-skilled labour decreased in the early years (1995–1999) and by then experienced an increase. As regards the share of high-skilled labour, no clear direction of development was observable, it fluctuated around the 3%-level throughout.

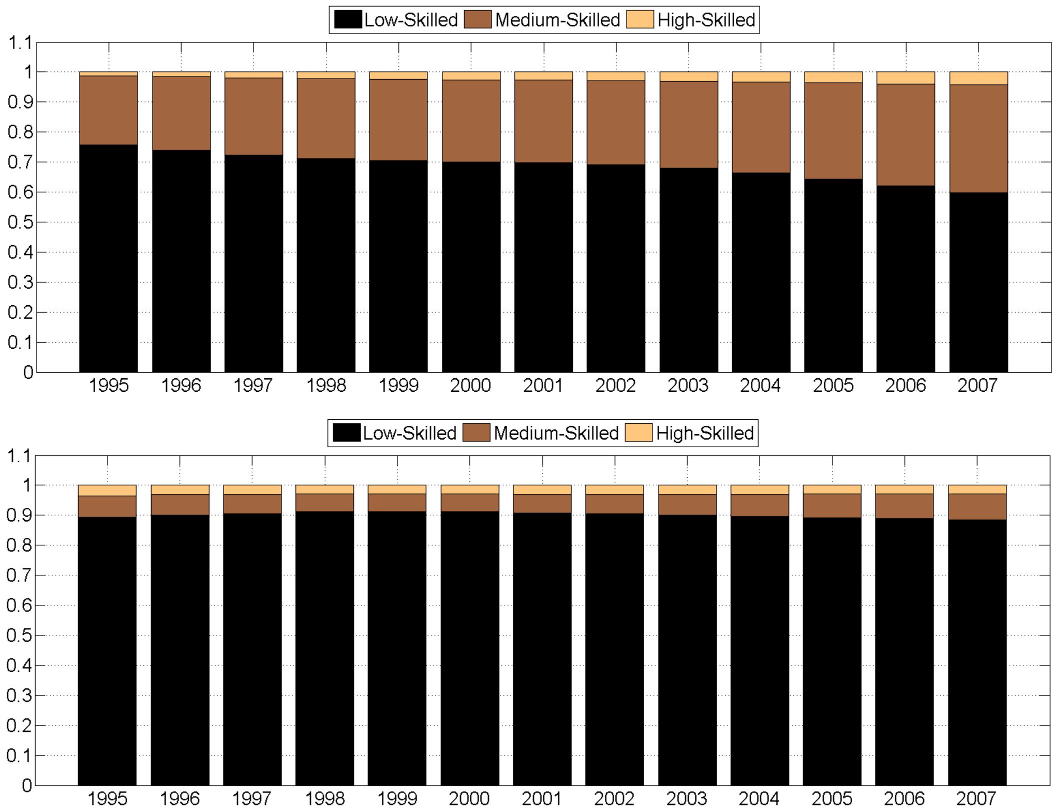

Figure 2: Skill-shares of direct hours worked in the C&T-industries of Italy (upper panel) and Portugal (lower panel), 1995–2007.
Data Source: EU Labour Force Survey (2014) and Timmer et al. (2015). Author's own calculations.

Our first findings indicate that learning activities going hand in hand with skills-upgrading took place in the two countries' C&T-industries, which started earlier in Italy than in Portugal. As can be seen from Table B2 in Appendix B, skill-type specific dynamics in Italy's benchmark sector followed more or less the same pattern, whereas dynamics in Portugal's low-tech sector differed to a good degree from those observed in its C&T-industry.

Yet, to gain deeper knowledge about innovation system-related-dynamics in their C&T-industries during the investigation period, this deserves a range of further indicators to be analysed, as reported in Section 4.2 and Section 4.3.

4.2 Product-Embodied Labour Flows and Patterns of Vertical Interaction

Qualitative composition of the labour content in Italian and Portuguese C&T-production: In a next step, we stick to both *direct* and *indirect* labour embodied in C&T-production as well as intertemporal changes therein, as illustrated in Figure 3.

With an average annual share of 59.8% in Italy and 85.6% in Portugal, low-skilled labour held the largest fraction in both countries. This was followed by medium-skilled labour (average annual share in Italy: 34% and in Portugal: 9.4%), whereas high-skilled labour on average accounted for the smallest fraction throughout (Italy: 6.3%, Portugal: 5%). This observation confirms the prevalent notion that the C&T-industry – more in Portugal than in Italy – has been typically a low-skill intensive industry. However, this does not preclude that the two C&T-industries shifted towards a higher medium- and high-skill intensity. Remarkable differences in skill-shares between the two countries – in particular with respect to low- and medium-skilled labour – further signalise that the character of C&T-production differed in both of them. Still for both countries, compared to skill-shares of direct hours worked, if adopting a subsystem perspective in both countries C&T-employment gets more medium- and high-skill intensive. This gives a first hint, that interaction with upstream producers was an important determinant of the qualitative composition of labour embodied in C&T-production during the observation period and that these interaction patterns might have induced an upgrading of skills of the working force.

Furthermore, the qualitative composition of labour experienced considerable dynamics in both countries C&T-industries. As can be seen in the upper panel of Figure 3, in Italy the development of each specific skill-share did not change sign over the whole time span but they evolved monotonically. Contrary for Portugal (Figure 3, lower panel), the development in the qualitative employment composition was not that evenly distributed across time. For each share of skill-type, the development experienced a reversal in sign.

Looking more closely, in Italy skills-upgrading took place gradually, and hence, direct and indirect hours worked in C&T-production got more medium- and high-skill intensive. This development was not limited to Italy's C&T-industry, intertemporal changes in the low-tech sector followed almost the same pattern (Appendix B, Table B3). Hence, in Italy innovation system-related-dynamics in the form of backward interaction between its C&T-industry and upstream producers favoured continuous learning activities, leading to a higher medium- and high-skill intensity.

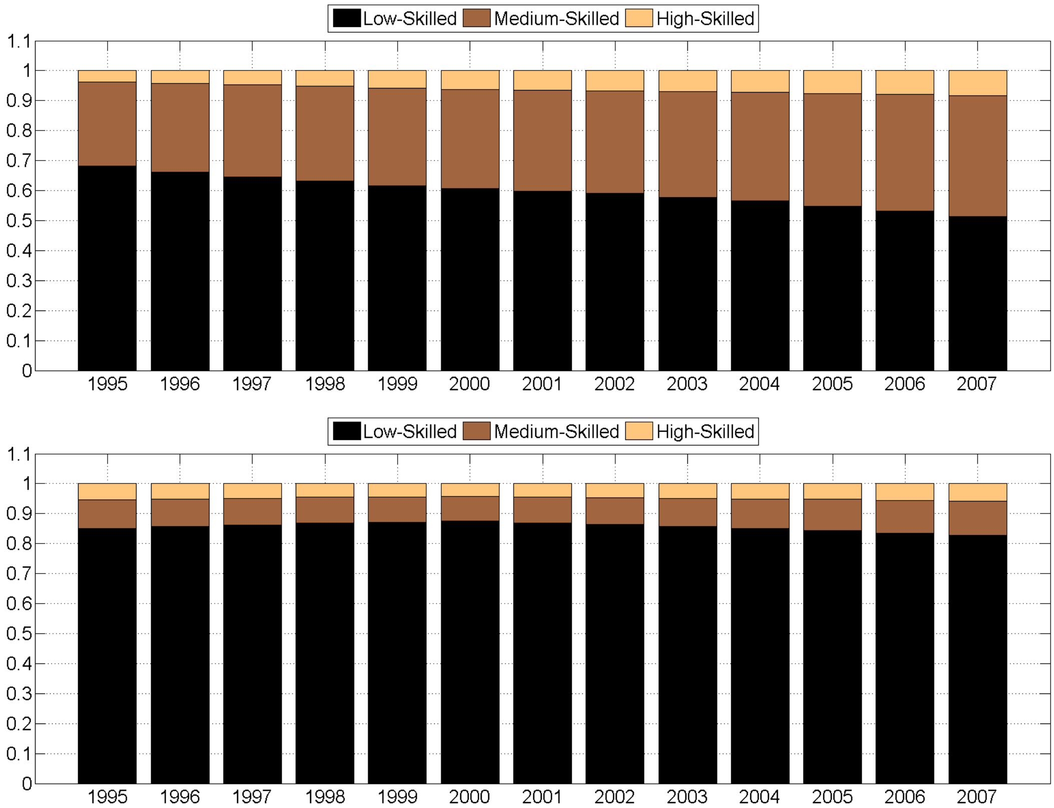

Figure 3: Skill-shares of direct and indirect hours worked in the vertically integrated C&T-industries of Italy (upper panel) and Portugal (lower panel), 1995–2007.
Data Source: EU Labour Force Survey (2014) and Timmer et al. (2015). Author's own calculations.

Turning to the development of the qualitative composition of employment in Portugal's C&T-industry, this was rather different compared to the situation observed in Italy. While the share of low-skilled labour increased in the early years of the observation period (1995–2000), it evolved into the opposite direction from 2000 to 2007. As regards the development of the shares of medium- and high-skilled hours worked, first of all, for the period from 1995 until 2000 each saw an annual decrease, while in the latter years of the observation period both accelerated. Also different from the Italian situation, in Portugal changes in the qualitative composition of C&T-employment were higher in magnitude than average changes in its benchmark sector (Appendix B, Table B3). Skill-specific dynamics show that in the Portuguese C&T-industry for the first time in 2000 a bias towards skills-upgrading prevailed, whereas counteracting tendencies were observed in the early years of the observation period. Hence, Portugal not until 2000 jumped on the bandwagon and only since then, innovation system-related-dynamics manifested in skills-upgrading and a gradual increase in the qualitative composition of the total labour content of C&T-production set in.

Internal and external sources of learning in C&T-production: In a next step, we explore whether changes in the qualitative composition of C&T-employment went hand in hand with a higher division of labour *between* industries or contrary, with an increased *vertical integration*. This gives an idea of whether sources of learning stemmed from within the C&T-industry or were of an external character (see Table 1).

As can be seen from Table 1, Portugal's C&T-industry with an average annual share of intra-industry labour flows of 73.3% was more vertically integrated during the whole observation period than Italy's (average annual share of 58.3%). In Italy in the years from 1995 until 2001 a tendency towards a lower degree of vertical integration prevailed, while from 2001 until 2007 the opposite was the case. In Portugal the situation evolved differently: over the whole time span C&T-production got more vertically integrated. This indicates that the Portuguese C&T-industry was relatively more cohesive and independent of other industries in terms of vertical interaction, whereas in Italy it perceived of comparatively stronger backward linkages. Additionally, this suggests that in Italy persistent mechanisms of inter-industry interaction enhanced the capability of C&T-production to engage in skills-upgrading and through interactive learning with upstream producers to achieve a higher medium- and high-skilled content of its final demand. Contrary, for Portugal a comparatively higher 'isolatedness' of its C&T-industry seems to have counteracted such developments, at least in the early years of the investigation period.

Noteworthy for both countries, the higher the skill-type the higher the degree of inter-industry interaction. This shows that in both countries with respect to medium- and high-skilled labour, external sources of learning were more important, whereas low-skilled labour embodied in intermediate inputs was abundant within C&T-production itself. However, still in Italy – apart from a few exceptional years – a steady increase in vertical integration of high-skilled labour took place. Together with an increased share of high-skilled labour in total direct hours worked, this substantiates previous results that in Italy skills-upgrading was also of an intra-industry character during the observation period. The same steady increase in vertical integration was observed in Portugal, but there it was for low-skilled labour, where intra-industry deliveries became more and more important. As regards medium- and high-skilled labour, the observed patterns in Portugal were rather diverse. In Italy, yearly changes in the degree of vertical integration of low-skilled labour fluctuated as well, whereas with only one exception the degree of vertical integration in terms of medium-skilled hours worked decreased from 1995 to 2001 and by then it increased throughout.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Ø
Italy														
Total Hours Worked	0.620	0.609	0.606	0.592	0.576	0.575	0.562	0.568	0.569	0.579	0.575	0.577	0.577	0.583
Low-Skilled	0.688	0.68	0.679	0.669	0.66	0.664	0.655	0.664	0.668	0.680	0.674	0.672	0.671	0.671
Medium-Skilled	0.508	0.504	0.510	0.496	0.478	0.475	0.460	0.466	0.471	0.486	0.491	0.504	0.515	0.490
High-Skilled	0.219	0.226	0.239	0.250	0.242	0.239	0.226	0.236	0.244	0.261	0.277	0.291	0.294	0.250
Portugal														
Total Hours Worked	0.708	0.709	0.704	0.712	0.728	0.741	0.732	0.742	0.744	0.749	0.756	0.752	0.754	0.733
Low-Skilled	0.742	0.745	0.740	0.748	0.764	0.773	0.765	0.777	0.781	0.788	0.798	0.800	0.805	0.771
Medium-Skilled	0.543	0.527	0.502	0.491	0.500	0.527	0.522	0.537	0.545	0.558	0.570	0.565	0.575	0.536
High-Skilled	0.453	0.444	0.438	0.434	0.466	0.505	0.497	0.493	0.474	0.455	0.431	0.393	0.384	0.451

Table 1: Share of intra-industry labour content in Italy's and Portugal's vertically integrated C&T-industries, 1995–2007.
Data Source: EU Labour Force Survey (2014) and Timmer et al. (2015). Author's own calculations.

Regarding dynamics prevailing in each country's benchmark sector (Appendix B, Table B4) – similar to their C&T-industries – the degree of vertical integration decreases with an increase in the skill-type. Over the whole time span, Italy's low-tech sector was less vertically integrated than Portugal's, showing that Italy's production of low-tech goods built more on backward linkages and this again was not an industry-specific phenomenon of C&T-production. In terms of skill-type specific developments of product-embodied labour flows, Italy's C&T-industry partly followed the dynamics experienced as well in its benchmark sector. In Portugal, however, intertemporal dynamics during the observation period in the vertically integrated low-tech industries differed to some extent from the situation observed in its C&T-production.

Interaction with upstream producers: Given the intensity of backward interaction, it is in question how this was distributed across upstream producers and *which* upstream producers did strongly interact with Italy's and Portugal's C&T-industries.[9] As illustrated in Figure 4, a high concentration with respect to the intensity of backward linkages prevailed in both countries' C&T-industries during the investigation period. Thus, the contribution of each single upstream producer in terms of the direct and indirect heterogeneous labour embodied in its deliveries to the C&T-industry was not evenly distributed at all. In Italy the average annual Gini-Index of total inter-industry hours worked was $G^I = 0.658$ and for Portugal it was even higher with $G^P = 0.731$.[10] For both countries concentration decreased on average in the early years, whereas in the latter years it accelerated again. With respect to different skill-types, the Gini-Indexes of backward linkages of the Portuguese C&T-industry were always more pronounced than the Italian ones. Together with previous results in terms of the degree of vertical integration this supports the finding that more active interaction with others and a non-isolated position of the Italian C&T-industry might have been beneficial to its development during the observation period. In Portugal sluggish inter-industry interaction seems to have prevented some potential of skills-upgrading.

Noteworthy, in Italy average annual concentration increases in the skill-type, whereas in Portugal it was the other way round. Hence, if one 'climbs up the quality-ladder' of inter-industry labour embodied in Italian (Portuguese) C&T-production, backward linkages got more concentrated (dispersed). For Portugal this implies that upstream producers contributed to the high-skill content of C&T-final demand in a rather equalised way. For Italy, however, this shows together with previous results regarding the degree of vertical integration that even though the degree of inter-industry interaction increases in the skill-type, it were only few upstream producers which strongly supported skills-upgrading in its C&T-industry.

[9] At this point, results for the two benchmark sectors are only reported in terms of the level of concentration of backward linkages but *not* with respect to the industries between whom interaction takes place, since this does neither give any additional value nor any explanatory power to the empirical evidence for the patterns observed in the C&T-industries of Italy and Portugal.

[10] As concerns the level of concentration of labour embodied in backward linkages within the benchmark sector, for both countries the average annual Gini-Index in the low-tech sector was even slightly higher.

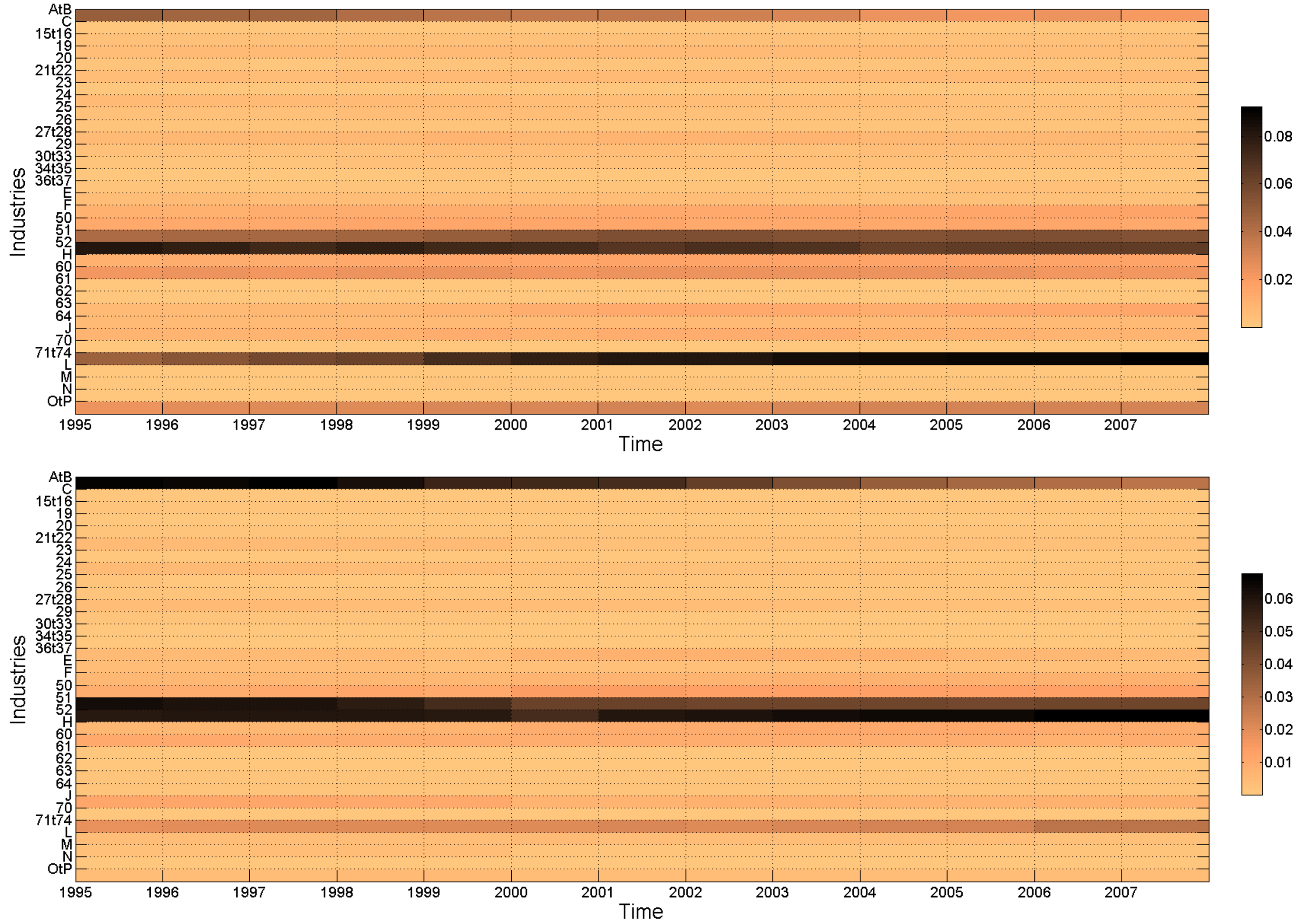

Figure 4: Intensity of backward linkages of the C&T-industries in terms of product-embodied labour flows in Italy (upper panel) and Portugal (lower panel), 1995–2007.
Data Source: EU Labour Force Survey (2014) and Timmer et al. (2015).

As can be seen from the upper panel of Figure 4, in Italy outstanding interaction between its C&T-industry and upstream producers with respect to total product-embodied labour flows took place with industry 52[11], which however got less important over time. Concentrating on other backward linkages belonging to the top-5 strongest ones, initially these were composed of sector AtB, which gradually lost in intensity as well, whereas interaction with industries 51 and 71t74 intensified. Among the top-5 strongest linkages interaction with sector PtO was found throughout the observation period as well and AtB was replaced by industry 60 in 2004. Inter-country differences with respect to the top-5 backward linkages as well as their development were hardly observable.

For Portugal (Figure 4, lower panel), the most intense backward linkage between its C&T-industry and sector AtB lost in importance, which was also the case for interaction with industry 51 and sector J. Contrary, the linkage between industry 71t74 and the Portuguese C&T-industry intensified, while that with industry 52 stayed relatively constant. Furthermore, interaction with industry 50 gradually gained in importance and this linkage outperformed that with industry J in 1998.

While industries 50, 51, 52 and 60 are usually perceived as low-skill intensive industries, intense interaction of the C&T-industries with them might have nevertheless been beneficial, since their closeness to end-users might have had a positive effect on learning in C&T-production. With respect to another rather traditional low-skill intensive upstream producer of the two countries' C&T-industries – namely, industry AtB – it is questionable whether interaction has contributed to skills-upgrading. By far more interestingly are the strong backward linkages to industries 71t74 and sector J which can be associated with 'knowledge intensive business services', characterised by an employment structure heavily weighted towards high-skilled workers and by a high potential to engage in interactive learning and to create new knowledge.

Turning to the dynamics of skill-type specific interaction patterns, since low-skilled labour was the dominating skill-type in total hours worked – its development patterns in both countries were very close to those of total hours worked during the observation period. Regarding medium-skilled and high-skilled labour, the top-5 strongest backward linkages were also similar to those of total labour in both countries throughout. Apart from a relatively constant ordering related to the top-5 strongest backward linkages, with decreasing intensity, skill-type specific differences were more pronounced.

Interestingly, for both countries the higher the skill-type, the more important was interaction with sector M. While for the Italian C&T-industry's the intensity of this backward linkage stayed relatively constant across time it lost in importance for Portugal's C&T-industry. Evidently, more for Italy's C&T-industry than for Portugal's, interactive learning through this channel remained an important source of skills-upgrading.

[11] A detailed list on industry-codes can be found in Table 1.

4.3 Results from Structural Decomposition of Employment Growth

Sticking finally to results from the SDA of employment growth, as can be seen from Table 2, in Italy – except for 1999–2000 and 2006–2007 – changes in total labour coefficients had the most intense impact (both negative and positive) on employment growth in its C&T-production. Changes in total labour coefficients, in 9 out of 12 periods went hand in hand with a growth in labour productivity. With respect to changes in skill-type specific labour coefficients, skills-upgrading in the Italian C&T-industry in the second half of the investigation period boosted total labour productivity growth – at the cost of low-skilled employment – and for some years was accompanied by gains in employment of medium- and high-skilled labour.

Impacts of dynamics in the Leontief-Inverse on total C&T-employment growth, which reflects changes in the overall industry-linkage structure, changed in sign during the early years of the investigation period (1995–2002) and from 2002 onwards, its dynamics caused a continuous reduction in total hours worked. In particular, this can be attributed to economy-wide changes in average production processes, which apart from 1997–1998 and 2001–2002, were of a labour-saving character. With a few exceptions the technological change effect was stronger in absolute magnitude than the import effect, signalising that economy-wide technological change was a more important determinant of employment dynamics in the Italian C&T-industry, than the effects of trade liberalisation.

Concerning dynamics experienced on average in Italy's low-tech sector (Appendix B, Table B5), changes in total labour coefficients had less frequently the dominant effect on employment growth compared to the situation observed in C&T-production. As regards their development, similar to C&T-production from 2001 onwards a continuous increase in total labour productivity was observed. Furthermore, impacts of changes in skill-type specific labour coefficients on C&T-employment growth partly followed the direction of average changes in the low-tech sector. Yet, changes of low-skilled and medium-skilled labour coefficients in Italy's C&T-industry were in general more pronounced compared to the low-tech sector. Also different from the situation of C&T-production, changes in intermediate import demand had a stronger absolute effect on employment more frequently than economy-wide changes in average production technologies. This supports the finding that Italy's C&T-production – despite the experienced trade liberalisation – reacted relatively more sensitive to innovation system-related-dynamics. Besides, more often than was the case in the C&T-industry, a positive effect on average employment in the low-tech sector arose from economy-wide changes in average production technologies, which confirms the observation that a strong labour-saving bias of changes in average production processes on C&T-employment was industry-specific.

Turning to partial effects determining C&T-employment growth in Portugal (see Table 2), different from the situation observed in Italy, changes in total labour coefficients only in 6 periods had the strongest (both negative and positive) impact on employment growth, while during the remaining year final demand changes were the most decisive factor.

	1995–96	1996–97	1997–98	1998–99	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07
Italy												
$g^{I,L}$	-0.043	-0.017	0.008	-0.077	-0.021	0.004	-0.010	-0.025	-0.031	-0.061	-0.049	-0.001
λ-Effect	-1.674	4.429	-2.348	-0.123	3.060	5.508	-4.000	-6.078	-2.735	-0.460	-0.875	-104.753
λ^l-*Effect*	-1.661	2.315	-3.115	-0.186	1.960	3.235	-3.436	-4.656	-2.332	-0.629	-1.000	-92.276
λ^m-*Effect*	-0.048	1.864	0.382	0.035	0.965	2.017	-0.587	-1.336	-0.412	0.124	0.089	-11.489
λ^h-*Effect*	0.035	0.25	0.385	0.028	0.134	0.256	0.023	-0.086	0.008	0.044	0.036	-0.988
$\mathbb{L}$-Effect	-0.332	-1.207	2.153	0.013	-0.658	-5.51	3.443	-0.204	-0.772	-0.097	-0.268	-5.225
TC-Effect	-0.586	-0.425	1.774	-0.059	-0.034	-5.593	2.734	-0.345	-0.763	-0.138	-0.104	-7.107
IM-Effect	-0.253	0.781	-0.379	-0.071	0.624	-0.083	-0.709	-0.141	0.009	-0.040	0.164	-1.882
y-Effect	1.006	-4.222	1.195	-0.890	-3.402	1.002	-0.444	5.283	2.506	-0.442	0.143	108.978
Portugal												
$g^{P,L}$	-0.023	-0.020	-0.011	-0.014	-0.022	-0.037	-0.023	-0.063	-0.026	-0.059	-0.088	-0.043
λ-Effect	1.154	2.640	-0.494	11.303	3.681	-0.815	1.867	-2.863	-3.811	0.160	-0.191	-2.038
λ^l-*Effect*	1.343	2.677	0.183	10.321	3.333	-0.862	1.540	-2.654	-3.593	0.093	-0.206	-1.923
λ^m-*Effect*	-0.112	-0.056	-0.41	0.58	0.242	0.034	0.256	-0.127	-0.086	0.080	0.027	-0.069
λ^h-*Effect*	-0.077	0.019	-0.267	0.401	0.107	0.013	0.071	-0.082	-0.132	-0.013	-0.012	-0.046
$\mathbb{L}$-Effect	-0.295	-0.348	-1.288	-2.278	0.169	0.013	-0.898	-0.084	-0.338	-0.169	-0.588	-0.204
TC-Effect	-0.094	0.226	0.376	-3.001	0.779	-0.101	-1.661	-0.162	-0.416	-0.350	-0.445	-0.271
IM-Effect	0.201	0.574	1.663	-0.723	0.61	-0.115	-0.763	-0.078	-0.078	-0.182	0.143	-0.068
y-Effect	-1.859	-3.293	0.782	-10.024	-4.851	-0.199	-1.969	1.947	3.149	-0.991	-0.221	1.241

Table 2: Structural decomposition of employment growth in Italy's and Portugal's C&T-industries, 1995–2007.
Note that (1) the technological change effect is abbreviated by 'TC-Effect'
and that the (2) the 'IM-Effect' describes the substitution of imported inputs for domestic inputs.
Values of partial effects are expressed as percent in decimal notation and sum thus up to 1.
Data Source: EU Labour Force Survey (2014) and Timmer et al. (2015). Author's own calculations.

This shows that employment in Portuguese C&T-production was more prone to changes on the demand side than to changes on the production side, compared to the Italian case. Impacts of changes in total labour coefficients were rather diverse throughout and also with respect to changes in skill-type specific labour-coefficients, these alternated in sign rather frequently.

Except for two periods – 1998–2000 – changes in the economy-wide production structure resulted in a reduction in Portuguese C&T-employment. Similar to the situation observed in Italy, but for different periods, the technological change effect in 8 out of 12 periods was stronger than the import effect. Regarding economy-wide changes in average production processes, this led to a reduction of employment in the Portuguese C&T-industry from 2000 onwards, and before its bias was sometimes labour-using and sometimes labour-saving. It is thus evident, that changes in economy-wide average production technologies in Portugal had a similar impact on C&T-employment growth as in Italy and that in the second half of the observation period factor-biased technological change appeared, leading to the substitution of labour for other inputs in C&T-production.

As regards dynamics in the Portuguese low-tech sector, the final demand effect was less frequently the dominant driver of employment growth compared to its C&T-industry. Furthermore, from 1995 until 2002 total labour coefficients rose, whereas from 2002 until 2007 labour productivity accelerated. It was observed as well that developments in skill-type specific labour coefficients in the Portuguese low-tech sector were relatively more homogeneous until 2002 than those of its C&T-industry, indicating that the restructuring process resulted in rather industry-specific dynamics at this time. Noteworthy, economy-wide changes in average production processes more often had a labour-using impact on average employment growth than was the case in the C&T-industry. Another remarkable difference to the Portuguese C&T-industry was found with respect to the absolute magnitude of the technological change and the import effect, where the latter in the low-tech sector was more frequently stronger than the former.

In a final step, the impact of technological change observed *within* both countries' C&T-industries on C&T-employment is discussed, as reported in Table 3. In Italy for 10 periods, changes in the average C&T-process technology generated a negative effect on its employment growth, and only for two periods had a labour-using impact. In Portugal changes in the average C&T-production technology, similar to the situation observed in Italy, were labour-using only for two periods and during the other periods caused a reduction of total hours worked in C&T-production. As illustrated in Appendix B (Table B6), in Italy labour-saving technological change was observed less frequently in its benchmark sector, whereas in the Portuguese benchmark sector, similar to its C&T-industry, labour-saving technological change prevailed in most periods. Thus, in this case the impact of innovation system-related-dynamics on Italy's C&T-employment did not follow aggregate patterns observed in its benchmark sector, whereas in Portugal similar patterns appeared.

	Italy	Portugal
1995–96	-0.01364	-0.00224
1996–97	-0.00432	0.00235
1997–98	0.00344	-0.00200
1998–99	-0.00118	-0.02379
1999–00	-0.00427	0.03578
2000–01	-0.01495	-0.00576
2001–02	0.01550	-0.02674
2002–03	-0.00300	-0.01061
2003–04	-0.01279	-0.00981
2004–05	-0.00638	-0.01506
2005–06	-0.00732	-0.02718
2006–07	-0.00133	-0.00647

Table 3: Impact of technological change in the C&T-industries of
Italy and Portugal on C&T-employment growth, 1995–2007.
Note that values are expressed as shares of the C&T-employment growth rate.
Data Source: EU Labour Force Survey (2014) and Timmer et al. (2015). Author's own calculations.

5 Conclusion

From low-tech to high-skill? Seeking to find an answer to this question, the main purpose of this paper was to contribute to a better understanding of innovation system-related-dynamics prevailing in Italy's and Portugal's C&T-industries in terms of interactive learning. We accounted for two different ways in which interactive learning might unfold, namely (1) skills-upgrading and (2) process innovations. The investigation period (1995–2007) was concentrated to a time, where this industry experienced deep economic restructuring merely in light of changes in the institutional environment. Since employment in the two C&T-industries came under pressure due to the before-mentioned restructuring, labour of different skill-types was considered an appropriate variable to answer the research question and to draw an accurate picture of the evolution of the two C&T-industries. From a more methodological perspective, studying employment dynamics by making use of the concept of product-embodied labour flows and of SDA proved successful, since various strong industry- and country-specific empirical patterns were figured out. To reconcile industry-specific dynamics, the low-tech sector of each country was used as a benchmark.

Starting with a short descriptive analysis, first hints were collected that it was in particular Italy's C&T-industry, where learning unfolded in skills-upgrading. Different from that, in Portugal efforts towards skills-upgrading were hardly observed until 2000.

In a next step the partial perspective was dropped and instead the evolution of the full labour content (both direct and indirect) embodied in C&T-production was investigated. This provided a thorough picture of the relationship between learning and skills-upgrading. As regards intertemporal dynamics, distinct developments towards a higher qualification of the working force became evident in Italy, which prevailed as well in its benchmark sector – despite at a lower level. In particular, it has been a strong linkage structure into which the Italian C&T-industry was embedded and an intense inter-industry interaction with upstream producers which have spurred this evolution. In Portugal, however, things initially evolved differently: C&T-production until 2000 got more low-skill intensive and only by then, learning activities through interaction with upstream producers were reinforced, reflecting in a slightly higher medium- and high-skilled labour content of its C&T-production.

While observed dynamics were relatively more industry-specific in Portugal than in Italy, the Portuguese C&T-industry during the whole time span was relatively more cohesive than the Italian, which might have prevented the establishment of intense interaction patterns favourable to a more interactive learning process. Still, for both countries it was only a handful of upstream producers, with whom strong interaction took place, even though some intertemporal shifts appeared. Especially interaction with knowledge intensive business service industries have been supporting the learning process which led to skills-upgrading in both C&T-industries.

With respect to results of the SDA, labour productivity growth together with economy-wide changes in average production processes were important determinants of C&T-employment in Italy throughout and in the second half of the observation period as well in Portugal. While in Italy the diffusion of economy-wide process innovations mostly had a negative impact on C&T-employment growth, this bias for Portugal was observed only after 2000. As regards changes in average production processes in the two C&T-industries, for both countries a strong skill-bias prevailed which resulted in a technology-skill-complementarity.

We conclude that both countries' C&T-industries evolved away from a typically low-tech, low-skill intensive towards a more medium- and high-skill intensive industry. Even though in Portugal innovation system-related-dynamics manifested later than in Italy, the performance of its innovation system was comparatively more strongly bound to the evolution of its C&T-industry, whereas in Italy innovation system-related-dynamics were less industry-specific but caused a more systemic change in its economic structure.

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Industry Classification

Industry	Industry ISIC Rev.3 Code
Agriculture, Hunting, Forestry and Fishing	AtB
Mining and Quarrying	C
Food, Beverages and Tobacco	15t16*
Textiles and Textile Products	17t18*
Leather, Leather and Footwear	19*
Wood and Products of Wood and Cork	20*
Pulp, Paper, Printing and Publishing	21t22*
Coke, Refined Petroleum and Nuclear Fuel	23
Chemicals and Chemical Products	24
Rubber and Plastics	25
Other Non-Metallic Mineral	26
Basic Metals and Fabricated Metal	27t28
Machinery, Nec.	29
Electrical and Optical Equipment	30t33
Transport Equipment	34t35
Manufacturing, Nec; Recycling	36t37*
Electricity, Gas and Water Supply	E
Construction	F
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	50
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	51
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	52
Hotels and Restaurants	H
Water Transport	61
Air Transport	62
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	63
Post and Telecommunications	64
Financial Intermediation	J
Real Estate Activities	70
Renting of M&Eq and Other Business	71t74
Public Administration and Defence; Compulsory Social Security	L
Education	M
Health and Social Work	N
Other Community, Social and Personal Services + Private Households with Employed Persons	OtP

Table 1: WIOD Industry Classification based on ISIC Rev.3. Note that industry-codes with an asterix correspond to low-tech industries.

Appendix A Structural Decomposition of Employment Growth

The growth rate of employment $g_{t-1,t}^{k,L}$ of a country k between two periods $t-1$ and t as formalised in equation (8), can change due to first, changes in labour coefficients $\Delta\lambda^k$, second, changes in the Leontief-Inverse $\Delta\mathbb{L}^k$, and third, changes in final demand Δy^k. Since structural decompositions are not unique and involve an index problem, this causes imprecision in results and difficulties in interpretation if more than two partial effects are distinguished – as is the case in this paper. Thus, the number of alternative decompositions rises with a factor $n!$, where n is the number of partial effects distinguished. To circumvent the index problem we apply a polar decomposition. Dietzenbacher and Los (1998) demonstrate that results of polar decompositions are remarkably close to results of the average of all possible decompositions. The 1st polar decomposition of equation (8), where variables are indexed by period t for country k reads as follows:

$$\lambda\lambda_t^k = \left(diag\left(\frac{1}{L_{t-1}^k e}\right) diag(\Delta\lambda^k)\mathbb{L}_t^k diag(y_t^k)\right)e \tag{A1a}$$

$$\mathbb{L}\mathbb{L}_t^k = \left(diag\left(\frac{1}{L_{t-1}^k e}\right) diag(\lambda_{t-1}^k)\Delta\mathbb{L}^k diag(y_t^k)\right)e \tag{A1b}$$

$$yy_t^k = \left(diag\left(\frac{1}{L_{t-1}^k e}\right) diag(\lambda_{t-1}^k)\mathbb{L}_{t-1}^k diag(\Delta y^k)\right)e \tag{A1c}$$

The 2nd polar decomposition, where year $t-1$ is used for indexing is given by:

$$\lambda\lambda_{t-1}^k = \left(diag\left(\frac{1}{L_{t-1}^k e}\right) diag(\Delta\lambda^k)\mathbb{L}_{t-1}^k diag(y_{t-1}^k)\right)e \tag{A2a}$$

$$\mathbb{L}\mathbb{L}_{t-1}^k = \left(diag\left(\frac{1}{L_{t-1}^k e}\right) diag(\lambda_t^k)\Delta\mathbb{L}^k diag(y_{t-1}^k)\right)e \tag{A2b}$$

$$yy_{t-1}^k = \left(diag\left(\frac{1}{L_{t-1}^k e}\right) diag(\lambda_t^k)\mathbb{L}_t^k diag(\Delta y^k)\right)e \tag{A2c}$$

Taking the average of the two polar decompositions of equations (A1a)–(A1c) and (A2a)–(A2c) the final decomposition of equation (8) can be written as:

$$\begin{gathered} g_{t-1,t}^{k,L} = 0.5\Big((\lambda\lambda_t^k + \lambda\lambda_{t-1}^k) + \\ (\mathbb{L}\mathbb{L}_t^k + \mathbb{L}\mathbb{L}_{t-1}^k) + (yy_t^k + yy_{t-1}^k)\Big) \end{gathered} \tag{A3}$$

Appendix A.1 Decomposition of Total Labour Coefficients

Changes in total labour coefficients $\Delta\lambda^k$ in country k are further decomposed into changes of skill-type specific labour coefficients $\Delta\lambda^{k,s}$. The 1st polar decomposition for a single skill-type $s = l, m, h$ is then given by:

$$\lambda\lambda_t^{k,l} = \left(diag\left(\frac{1}{L_{t-1}^k e}\right) diag(\Delta\lambda^{k,l})\mathbb{L}_t^k diag(y_t^k)\right)e \tag{A4a}$$

$$\lambda\lambda_t^{k,m} = \left(diag\left(\frac{1}{L_{t-1}^k e}\right) diag(\Delta\lambda^{k,m})\mathbb{L}_t^k diag(y_t^k)\right)e \tag{A4b}$$

$$\lambda\lambda_t^{k,h} = \left(diag\left(\frac{1}{L_{t-1}^k e}\right) diag(\Delta\lambda^{k,h})\mathbb{L}_t^k diag(y_t^k)\right)e \tag{A4c}$$

The 2nd polar decomposition reads as:

$$\lambda\lambda_{t-1}^{k,l} = \left(diag\left(\frac{1}{L_{t-1}^k e}\right) diag(\Delta\lambda^{k,l})\mathbb{L}_{t-1}^k diag(y_{t-1}^k)\right)e \tag{A5a}$$

$$\lambda\lambda_{t-1}^{k,m} = \left(diag\left(\frac{1}{L_{t-1}^k e}\right) diag(\Delta\lambda^{k,m})\mathbb{L}_{t-1}^k diag(y_{t-1}^k)\right)e \tag{A5b}$$

$$\lambda\lambda_{t-1}^{k,h} = \left(diag\left(\frac{1}{L_{t-1}^k e}\right) diag(\Delta\lambda^{k,h})\mathbb{L}_{t-1}^k diag(y_{t-1}^k)\right)e \tag{A5c}$$

Taking the average of the two polar decompositions of equations (A4a)–(A4c) and (A5a)–(A5c), changes in labour coefficients $\Delta\lambda^k$ are determined by:

$$\Delta\lambda^k = 0.5\Big(\big(\lambda\lambda_t^{k,l} + \lambda\lambda_{t-1}^{k,l}\big) + \big(\lambda\lambda_t^{k,m} + \lambda\lambda_{t-1}^{k,m}\big) + \big(\lambda\lambda_t^{k,h} + \lambda\lambda_{t-1}^{k,h}\big)\Big) \tag{A6}$$

Appendix A.2 Decomposition of the Leontief-Inverse

Finally, changes in the Leontief-Inverse are decomposed into first, changes in average production technology, and second, changes in the input structure arising through a substitution of imported inputs for domestic inputs. Let $Z^{k,M}$ be a $n \times n$ matrix containing imported intermediate transaction flows. Then the matrix of import coefficients for country k is determined by $A^{k,M} = Z^{k,M}(diag(x^k))^{-1}$. It holds further that the matrix of technological coefficients is the sum of the matrix of input coefficients and import coefficients, defined by $A^k \equiv A^{k,D} + A^{k,M}$. Given that $\mathbb{L}_t^k = (\mathbb{I} - A_t^{k,D})^{-1}$ and $\mathbb{L}_{t-1}^k = (\mathbb{I} - A_{t-1}^{k,D})^{-1}$, changes in $\Delta\mathbb{L}^k$ can be further decomposed into the before-mentioned effects after a few mathematical steps have been conducted.

Following Miller and Blair (2009), this involves first post-multiplying of $\mathbb{L}_t^k$ by $(\mathbb{I} - A_t^{k,D})$:

$$\mathbb{L}_t^k(\mathbb{I} - A_t^{k,D}) = \mathbb{I} = \mathbb{L}_t^k - \mathbb{L}_t^k A_t^{k,D} \tag{A7a}$$

Second, pre-multiplying $\mathbb{L}_{t-1}^k$ by $(\mathbb{I} - A_{t-1}^{k,D})$ yields:

$$(\mathbb{I} - A_{t-1}^{k,D})\mathbb{L}_{t-1}^k = \mathbb{I} = \mathbb{L}_{t-1}^k - A_{t-1}^{k,D}\mathbb{L}_{t-1}^k \tag{A7b}$$

Rearranging equation (A7a) and post-multiplying by $\mathbb{L}_{t-1}^k$; and rearranging in a further step equation (A7b) and pre-multiplying by $\mathbb{L}_t^k$ gives:

$$\mathbb{L}_t^k - \mathbb{I} = \mathbb{L}_t^k A_t^{k,D} \Rightarrow \mathbb{L}_t^k\mathbb{L}_{t-1}^k - \mathbb{L}_{t-1}^k = \mathbb{L}_t^k A_t^{k,D}\mathbb{L}_{t-1}^k \tag{A8a}$$

$$\mathbb{L}_{t-1}^k - \mathbb{I} = A_{t-1}^{k,D}\mathbb{L}_{t-1}^k \Rightarrow \mathbb{L}_t^k\mathbb{L}_{t-1}^k - \mathbb{L}_t^k = \mathbb{L}_t^k A_{t-1}^{k,D}\mathbb{L}_{t-1}^k \tag{A8b}$$

Subtracting in a last step the right-hand side of equation (A8b) from that of equation (A8a), one arrives at:

$$\Delta\mathbb{L} = \mathbb{L}_t^k A_t^{k,D}\mathbb{L}_{t-1}^k - \mathbb{L}_t^k A_{t-1}^{k,D}\mathbb{L}_{t-1}^k = \mathbb{L}_t^k(\Delta A^{k,D})\mathbb{L}_{t-1}^k \tag{A9}$$

Given $A^{k,D} = A^k - A^{k,M}$, equation (A9) can be written as:

$$\begin{aligned}\Delta\mathbb{L} &= \mathbb{L}_t^k \left((A_t^k - A_t^{k,M}) - (A_{t-1}^k - A_{t-1}^{k,M})\right)\mathbb{L}_{t-1}^k \\ &= \mathbb{L}_t^k \Delta A^k \mathbb{L}_{t-1}^k - \mathbb{L}_t^k \Delta A^{k,M}\mathbb{L}_{t-1}^k\end{aligned} \tag{A10}$$

The first term on the right-hand side of equation (A10), $\mathbb{L}_t^k \Delta A^k \mathbb{L}_{t-1}^k$ describes technological change, and the second $\mathbb{L}_t^k \Delta A^{k,M}\mathbb{L}_{t-1}^k$ the substitution of imported inputs for domestic inputs, as described in Magacho (2013). Taking the right-hand side of equation (A10) and indexing through by t yields the 1st polar decomposition:

$$AA_t^k = \left(diag\left(\frac{1}{L_{t-1}^k e}\right)diag(\lambda_{t-1}^k)\mathbb{L}_t^k\Delta A^k\mathbb{L}_{t-1}^k diag(y_t^k)\right)e \tag{A11a}$$

$$AA_t^{k,M} = \left(diag\left(\frac{1}{L_{t-1}^k e}\right)diag(\lambda_{t-1}^k)\mathbb{L}_t^k\Delta A^{k,M}\mathbb{L}_{t-1}^k diag(y_t^k)\right)e \tag{A11b}$$

Indexing through by $t-1$, the 2nd polar decomposition is given by:

$$AA_{t-1}^k = \left(diag\left(\frac{1}{L_{t-1}^k e}\right)diag(\lambda_t^k)\mathbb{L}_t^k\Delta A^k\mathbb{L}_{t-1}^k diag(y_{t-1}^k)\right)e \tag{A12a}$$

$$AA_{t-1}^{k,M} = \left(diag\left(\frac{1}{L_{t-1}^k e}\right)diag(\lambda_t^k)\mathbb{L}_t^k\Delta A^{k,M}\mathbb{L}_{t-1}^k diag(y_{t-1}^k)\right)e \tag{A12b}$$

Taking the average of equations (A11a)–(A11b) and (A12a)–(A12b), finally one arrives at:

$$\Delta\mathbb{L}^k = 0.5\Big(\big(AA_{t-1}^k + AA_t^k\big) - \big(AA_{t-1}^{k,M} + AA_t^{k,M}\big)\Big) \tag{A13}$$

Appendix B Additional Statistics

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Italy													
Low-Skilled	0.678	0.674	0.669	0.666	0.661	0.658	0.652	0.643	0.631	0.614	0.597	0.580	0.562
Medium-Skilled	0.299	0.301	0.302	0.303	0.305	0.306	0.309	0.315	0.323	0.335	0.348	0.361	0.375
High-Skilled	0.022	0.025	0.028	0.031	0.034	0.036	0.039	0.042	0.046	0.050	0.055	0.059	0.063
Portugal													
Low-Skilled	0.854	0.856	0.855	0.858	0.852	0.845	0.843	0.840	0.836	0.828	0.820	0.809	0.797
Medium-Skilled	0.103	0.100	0.099	0.096	0.097	0.100	0.102	0.104	0.105	0.108	0.111	0.114	0.118
High-Skilled	0.043	0.044	0.046	0.047	0.051	0.054	0.055	0.056	0.059	0.063	0.069	0.078	0.085

Table B2: Average skill-shares of direct hours worked in the low-tech sectors of Italy and Portugal, 1995–2007.
Data Source: EU Labour Force Survey (2014) and Timmer et al. (2015). Author's own calculations.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Italy													
Low-Skilled	0.636	0.625	0.615	0.607	0.596	0.588	0.582	0.571	0.555	0.542	0.528	0.514	0.498
Medium-Skilled	0.320	0.327	0.331	0.335	0.341	0.345	0.348	0.356	0.367	0.376	0.388	0.398	0.409
High-Skilled	0.044	0.049	0.054	0.058	0.064	0.067	0.070	0.074	0.078	0.081	0.085	0.088	0.094
Portugal													
Low-Skilled	0.840	0.841	0.842	0.844	0.842	0.843	0.839	0.834	0.827	0.817	0.807	0.792	0.780
Medium-Skilled	0.103	0.103	0.102	0.101	0.102	0.102	0.104	0.106	0.109	0.113	0.116	0.122	0.126
High-Skilled	0.056	0.056	0.056	0.055	0.056	0.055	0.057	0.060	0.064	0.070	0.076	0.086	0.094

Table B3: Average skill-shares of direct and indirect hours worked in the vertically integrated low-tech sectors of Italy and Portugal, 1995–2007.
Data Source: EU Labour Force Survey (2014) and Timmer et al. (2015). Author's own calculations.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Italy													
Total Hours Worked	0.514	0.507	0.502	0.499	0.491	0.491	0.487	0.488	0.480	0.490	0.489	0.495	0.493
Low-Skilled	0.551	0.549	0.548	0.549	0.548	0.552	0.549	0.552	0.546	0.555	0.553	0.556	0.554
Medium-Skilled	0.469	0.457	0.449	0.441	0.429	0.427	0.422	0.423	0.415	0.427	0.432	0.443	0.447
High-Skilled	0.237	0.234	0.235	0.242	0.236	0.237	0.242	0.253	0.252	0.268	0.280	0.294	0.298
Portugal													
Total Hours Worked	0.529	0.533	0.534	0.543	0.548	0.543	0.537	0.548	0.545	0.552	0.553	0.543	0.545
Low-Skilled	0.544	0.548	0.547	0.556	0.557	0.547	0.542	0.554	0.553	0.561	0.564	0.557	0.560
Medium-Skilled	0.473	0.469	0.468	0.468	0.474	0.483	0.470	0.474	0.465	0.466	0.469	0.454	0.461
High-Skilled	0.367	0.381	0.398	0.406	0.415	0.431	0.410	0.402	0.390	0.396	0.401	0.394	0.411

Table B4: Average share of intra-industry labour content in Italy's and Portugal's vertically integrated low-tech sectors, 1995–2007.
Data Source: EU Labour Force Survey (2014) and Timmer et al. (2015). Author's own calculations.

	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Italy												
g^L	-0.025	-0.021	0.017	-0.013	-0.020	-0.015	0.002	-0.019	-0.010	-0.043	-0.009	0.007
λ-Effect	-2.518	2.073	0.144	0.726	3.606	0.747	-20.698	-9.892	-9.507	-0.606	-2.988	-12.663
λ^l-*Effect*	-1.885	1.176	-0.103	0.197	2.208	0.073	-19.529	-6.949	-7.402	-0.769	-3.764	-9.576
λ^m-*Effect*	-0.692	0.693	0.077	0.314	1.167	0.454	-2.757	-2.694	-2.053	0.094	0.473	-2.867
λ^h-*Effect*	0.059	0.205	0.170	0.214	0.231	0.220	1.588	-0.249	-0.051	0.069	0.304	-0.221
$\mathbb{L}$-Effect	-0.126	0.329	0.910	0.854	-0.255	0.569	5.990	0.212	-0.721	-0.322	-2.219	0.503
TC-Effect	-0.795	0.698	1.052	0.590	0.740	0.502	2.804	0	-0.237	-0.283	-0.836	0.664
IM-Effect	-0.670	0.369	0.142	-0.264	0.996	-0.066	-3.186	-0.212	0.484	0.039	1.384	0.161
y-Effect	1.644	-3.402	-0.054	-2.58	-4.351	-2.316	15.708	8.68	9.228	-0.072	4.207	13.161
Portugal												
g^L	0.006	-0.010	0.001	-0.013	-0.020	-0.012	-0.008	-0.033	-0.021	-0.025	-0.06	-0.024
λ-Effect	8.341	6.482	30.156	8.86	3.822	2.299	2.161	-5.808	-5.512	-0.105	-1.032	-5.451
λ^l-*Effect*	7.170	5.247	28.311	7.417	2.725	2.037	1.48	-4.898	-4.87	-0.373	-0.939	-4.753
λ^m-*Effect*	0.627	0.635	-0.639	0.819	0.640	0.204	0.465	-0.612	-0.485	0.057	-0.105	-0.494
λ^h-*Effect*	0.54	5 0.600	2.484	0.624	0.457	0.058	0.216	-0.298	-0.157	0.211	0.012	-0.204
$\mathbb{L}$-Effect	-0.517	-0.337	-12.08	-1.796	-0.895	0.234	-2.789	-0.048	-0.383	-0.181	-0.274	-0.164
TC-Effect	0.143	0.456	8.371	-2.051	-0.403	0.437	-3.835	-0.130	0.129	-0.305	-0.256	0.180
IM-Effect	0.661	0.793	20.451	-0.255	0.492	0.202	-1.047	-0.082	0.512	-0.124	0.018	0.345
y-Effect	-6.824	-7.145	-17.076	-8.065	-3.927	-3.533	-0.373	4.856	4.895	-0.715	0.306	4.615

Table B5: Structural decomposition of average employment growth in Italy's and Portugal's low-tech sectors, 1995–2007.
Note that (1) the technological change effect is abbreviated by 'TC-Effect' and
that the (2) the 'IM-Effect' describes the substitution of imported inputs for domestic inputs.
Values of partial effects are expressed as shares of the C&T-employment growth rate.
Data Source: EU Labour Force Survey (2014) and Timmer et al. (2015). Author's own calculations.

	Italy	Portugal
1995-96	-0.00798	-0.00554
1996-97	0.00488	0.00135
1997-98	0.00563	-0.00033
1998-99	0.00329	-0.00623
1999-00	0.00425	0.00609
2000-01	0.00365	0.00350
2001-02	0.00121	-0.00894
2002-03	0.00183	-0.00585
2003-04	-0.00829	-0.00555
2004-05	-0.00608	-0.00484
2005-06	-0.00314	-0.00979
2006-07	0.00390	0.00312

Table B6: Average impact of technological change in the low-tech sectors of Italy and Portugal on average sectoral employment growth, 1995–2007.
Values are expressed as shares of the C&T-employment growth rate.
Data Source: EU Labour Force Survey (2014) and Timmer et al. (2015). Author's own calculations.