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Abstract

Growing shares of international trade flows consist of intermediate and unfinished goods shipped from one country to another to combine manufacturing or services activities at home with those performed abroad. This configuration of the productive structure has been named "internationally fragmented". The purpose of our work is to analyze the labor market effects of international fragmentation of production in Europe, looking at how it affects relative labor demand. Models of trade due to fragmentation of production suggest that when international fragmentation takes place we can expect to observe a change in the relative factor intensities of the affected industries. We use international trade data specifically related to international fragmentation of production to test if the shift in intensity of skilled and unskilled labor employed in Italy and Germany during the 1990s it related to the fragmentation activity.

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1. Introduction

Recently, both theoretical and applied research have been devoting increasing attention to the fact that large and growing shares of international trade flows consist of intermediate and unfinished goods shipped from one country to another to combine manufacturing or services activities at home with those performed abroad. The new configuration of the productive structure underlying such phenomena has been named "internationally fragmented".[1] Interest in international fragmentation of production (IFP) is due to the many – sometimes unexpected – effects it has on organization of production, on trade flows and international specialization, distribution of income and labor markets.

The existing (but limited) empirical work in this field suggests that differences in factors' prices, and labor cost differentials especially, are one of the main driving forces of international fragmentation. In Europe, the persistent wage gap between EU members and countries in Eastern Europe and in the Mediterranean Basin explains to a large extent the decision by EU firms to transfer abroad more or less extensive segments of previously integrated production processes. But also geographic and cultural proximity plays a key role in the choice of localization. In many industries, delocalization of production appears to be a response to the increasing competitive pressure exerted by low-cost producers on European firms (Baldone *et al*., 2002).

Starting from these findings, the purpose of our work is to analyze the labor market effects of international fragmentation of production in Europe, looking at how it affects relative labor demand. Models of trade due to fragmentation of production indicate that, when international fragmentation takes place, we can expect to observe a change in the relative factor intensities of the affected industries. We want to test if this shift in intensity of factor usage is observable in Europe and if it relates to the fragmentation activity. But theoretical models of IFP indicate also that the sign of the effects of fragmentation on labor demand is *a priori* ambiguous, as it depends upon the relative factor intensity of the industries that fragment production, on which production phases are delocalized, and toward which countries. Therefore, the effects of fragmentation on labor markets turn out to be an empirical matter. We aim at producing empirical evidence showing the relationship between delocalization of production phases and the composition of employment in European countries.

[1] Many different terms have been used in the literature for this phenomenon: vertical integration, delocalization, production sharing, super-specialization are a few examples (see Arndt and Kierzkowski, 2001; Deardorff, 2001a; Hummels et. al., 2001; Feenstra, 1998) The proliferation of names indicates the interest raised by this form of production and trade. At the same time, the absence of a commonly accepted terminology suggests that the phenomenon is still ambiguously defined, as it is a relatively new and innovative aspect of the economic relations between countries.

The issue is not new and it is linked to the extensive debate on the relationship between globalization and the labor markets, which generated a large number of theoretical and empirical studies. In particular, a recent strand of literature focused on the impact of outsourcing and import of intermediate goods on the labor market and on wage differentials. Earlier works on these issues by Feenstra and Hanson (1996, 1999) and Hanson (1996) focused on the U.S., which saw an increase in international fragmentation as trade in goods' parts and intermediates with a number of comparatively low-wage countries (Mexico, first of all) was facilitated by the decline in commercial barriers. Europe experienced a similar phenomenon especially thanks to the re-integration of the formerly planned economies of Central and Eastern Europe into world markets. A few recent papers examine the impact of fragmentation on the labor markets in some European countries (Anderton and Brenton, 1999; Dell'mour et al., 2000; Gorg et. al., 2001; Strauss-Kahn, 2002).

The specific contribution of this paper is to extend such investigation to the cases of Italy and Germany. These two countries' characteristics make them interesting to analyze in this context, because both countries are highly involved in the recent wave of trade with Central and Eastern Europe, and the Italian and German light industries (especially responsive to fragmentation of production) play an important role in their economies. The other specificity of this paper is the use of a strictly-defined measure of international fragmentation of production – trade flows for reason of processing – that allows us to pinpoint the international linkages between production phases much better than general indices of import penetration used in other analyses. The paper is organized as follows: the next section provides the theoretical background for our empirical investigation; section three presents the data set and the stylized facts on international fragmentation of production and on the change in skill intensity in production, identifying the sectors most affected by the phenomena and the countries toward which fragmentation is directed. Section four is devoted to the econometric analysis of the relationship between IFP and change in skill intensity, in order to assess whether fragmentation has changed the demand for skilled and unskilled labor in the countries examined, and the main conclusions are presented in section five.

2. Models of international fragmentation of production

International fragmentation of production is defined as the process whereby previously integrated production activities are segmented and spread over an international network of production sites. The coordination of production activities taking place in different countries is likely to require some extra costs to pay for the needed services: transportation of goods between

production locations, quality controls, etc. (Jones and Kierkowski, 2001). But as long as integrated production remains available, fragmentation of production will be adopted only if it does not increase overall production costs, and even more so if it is a cost-saving strategy. Therefore, specific circumstances are required for fragmentation to take place, as additional coordination costs must be offset by a reduction in other production costs.[2] International fragmentation of production can save costs mainly for two reasons: at given factor costs, the sum of segments of production needed to obtain the final good absorbs less production factors than integrated production (in this case, fragmentation would be a form of technical progress); or factor price differentials between countries allow at least one fragment to be produced more cheaply in another country (Deardorff, 2001b).

Here we will focus on the second case, which can arise when countries lie in different cones of diversification, so that even when trading, factor price differences will persist between them. Consider two (groups of) countries, that we call West and East respectively, the first relatively abundant in skilled labor and the other relatively abundant in unskilled labor, with different factor prices and using skilled and unskilled labor to produce different sets of goods under free trade. Suppose that fragmentation of the technology for producing good X (originally produced in the West) becomes possible. What happens is described in Figure 1. Before fragmentation took place, good X was produced using the factor combination implied by the slope of ray OI in the figure, falling within the Western cone. With fragmentation, the same amount (one Euro worth) of the final good X can be produced combining two production segments with different factor combinations, OZ and ZI. It can be observed that while the slope of segment OZ is such that it will be cheaper to produce the intermediate good in the West, the slope of segment ZI makes its production more profitable in the East.[3] Even if the sum of the two segments passes point I (that is to say, it requires a larger amount of factors), this technology may still reduce costs as long as each segment is produced in the "right" country and factor prices differentials are large enough (Deardorff 2001b). In this case, the sum of the *costs* for producing the two segments will be lower that the cost of integrated production. The larger the factor prices differentials and the more different are factor intensities in the two segments, the more fragmentation will reduce costs.

[Figure 1 about here]

[2] Antras and Helpman (2003) present a model showing that because of the trade-off between different types of costs, international fragmentation of production (or foreign outsourcing, in their terminology) will be convenient only for some category of firms.

[3] To exemplify, X can represent consumer electronics, segment OZ represents microchips and other electronic components and segment ZI represents plastic parts and assembly of the final good. Alternatively, one could think of X as the textile and apparel industry, where textile production and apparel design are the skill-intensive segments and sewing and finishing are the less skill-intensive parts.

What happens if the fragmented technology is indeed adopted (and if it is economical, it becomes the only way to produce good X)? West will no longer produce the final good X, but only some components of it, which are more skill-intensive than the overall production of X, as shown in Fig.1 by the steeper slope of segment 0Z. The unskill-intensive part of production will be moved to the East, to use the factor combination shown by the slope of segment ZI. This fragmentation of production will bring about a number of consequences. First of all, a new industry (or a part of it) will start in the East. The East was not producing X and would not produce OZ in free trade, but when the input OZ becomes available from abroad, it turns out that it is worth it for the East to produce good X by assembling the imported segment OZ with the domestic production ZI. Therefore, different trade flows will appear between the countries involved, as intermediate goods are shipped from one production location to another.[4] Furthermore, there will be a number of changes taking place in the West. Total output in the fragmented industry might increase or decrease, depending upon other adjustments taking place.[5] What is more relevant here is that the sector which is moving abroad its unskill-intensive phases of production and maintaining the domestic production of its skill-intensive phases will experience an increase in the relative demand for skilled labor. If the industry experiencing fragmentation is large enough compared to the overall economy, this will also affect the equilibrium in other sectors through its effects on relative wages or employment, according to the labor market characteristics. If we have general equilibrium effects, the change in relative factor prices depends on how the factor proportions of fragments compare to the average factor intensities within the country's cone.[6] Therefore, fragmentation might in principle push factor prices in either direction, thereby reducing or increasing differences between countries (Deardorff, 2001b). But even leaving general equilibrium effects aside, the fragmented industry will certainly experience a change in its production pattern and in its relative demand for factors.

In what follows, we look at what happens to the skill composition of the employed workforce at the industry level. Given that theoretical models of fragmentation suggest that the direction of change depends on the specific circumstances under which fragmentation is taking place, the problem will be tackled empirically. We will estimate whether the recourse to

[4] See Deardorff (2003) for a discussion of changes in trade patterns when intermediate goods are tradable.
[5] With more than two cones, both production segments could be moved abroad, and the industry could even disappear from the country originally producing the final good.
[6] In this framework, the relative wage of unskilled workers might increase, even if low skill-intensive phases of production are delocalized (cfr. Jones and Kierzowski, 2001). In fact, if the segment still produced domestically is relatively unskilled-intensive compared to the entire economy and its output increases (because fragmentation has boosted the competitiveness of the sector), the average relative demand for unskilled labor in the economy might increase.

international fragmentation of production caused shifts in the production functions that affect the labor force employment.

The empirical methodology used in this paper is based on the work by Berman et al. (1994), where they try to identify the causes of changes in the demand for skilled labor in the U.S. Initially, their main candidates are increased international competition and labor-saving technological change. Their results show that most of the shift toward skilled employment in the U.S. in the 1980s occurred within manufacturing industries and they infer a predominant role for unskilled labor-saving technological change in explaining the shift of demand toward skilled labor.

But in presence of international fragmentation of production, it is not straightforward to disentangle the effects of international trade and technological change, because international fragmentation entails both a change in technology *and* an increase in trade flows. If a given amount of final output is obtained with a smaller amount and/or a different proportion of *domestic* factors of production combined with *foreign* factors of production embodied through the delocalization abroad of some production phases, IFP will appear in the data as a specific form of technological change, accompanied by a parallel increase in imports of intermediate or semi-finished goods. Therefore, for countries highly involved in international fragmentation, the distinction between "trade effects" and "technology effects" on labor demand might be inappropriate. We rather see IFP as a distinct – and to a large extent measurable – cause of shift in labor demand, possibly in addition to other forms of technological change and "traditional" trade.

3. Empirical evidence on international fragmentation of production

3.1 Data on international fragmentation of production and skill employment

The first step in our empirical analysis is the presentation of a broad picture of outward fragmentation of production in Italy and Germany to determine the sectors where it is most relevant. As mentioned, these two countries are both very active in IFP, especially toward Central and Eastern Europe. Germany in particular is the country originating the largest share of European traffic for reason of processing and it started to use this practice massively in some sectors more than a decade ago (see Baldone *et al*., 2001).

To analyze the effects of IFP, we use a very narrow measure of this phenomenon, that is outward processing trade (OPT) flows. The Comext database from Eurostat collects trade flows registered as "trade for reasons of processing" (goods temporarily exported from the EU to be

processed abroad and eventually re-imported into the EU) using the Combined Nomenclature and the definitions adopted by the EU legislation. OPT data is a conservative and not exhaustive measure of the phenomenon of international fragmentation (as not all trade in intermediate and unfinished goods to be processed abroad is recorded as OPT according to Eurostat definition), but we believe that these are the most reliable data available for Europe at a highly disaggregated level, both sectorally and geographically. Furthermore, such a narrow measure should give us a better picture of the specific phenomenon we want to observe: not the general recourse to international outsourcing, but a re-organization of the production process toward what is sometimes called "production sharing", in which a firm not only buys intermediate inputs abroad, but it chooses to delocalize abroad a specific segment of its production, deciding exactly which phases of production are delocalized and how the processing is done abroad. This choice should have a very direct impact on the firm's demand for domestic factors.

To assess which industries are most affected by IFP, the basic disaggregated OPT data from Eurostat were re-aggregated to obtain a classification comparable to the existing classification of industrial activities (ISIC). With this new classification of OPT data we were able to calculate the incidence of fragmentation over domestic production. By computing the ratio of the value of re-imported goods that were processed abroad over the value of domestic production, it is possible to see that in many industries this new form of organization of production is non-negligible even when adopting such a narrow indicator, confirming also for Germany and Italy what has been observed in other studies.[7] In order to distinguish between different reasons for fragmentation we also disaggregated geographically the composition of OPT, as the nature of OPT toward low-wage countries, supposedly belonging to another cone of diversification, is clearly different than OPT toward countries with similar endowments and factor costs.

The other key variable in our analysis is relative employment of skilled and unskilled workers. The reason to consider this variable rather than wage differentials between groups of workers is two-fold: the direct impact of delocalization decisions by firms should be on employment composition, and furthermore in Europe the labor market characteristics imply that wages are not very responsive (at least in the short-medium run) to changes in labor demand.[8] Therefore, we expect relative employment to be more sensitive to changes such as the recourse to international fragmentation of production.

[7] See for example Hummels *et al*. (2001).

[8] The characteristics of the European labor markets have been examined in the literature linking globalization and labor markets, showing that different effects result from different institutional contexts. The shared view is that in continental Europe shocks affect primarily employment levels rather than wages, as is instead the case in the U.S. See for example Davis (1998).

Data on employment of workers by industry are taken from national statistical offices' publications for 20 manufacturing sectors. The maximum level of disaggregation available corresponds to 2-digit ISIC rev.3. We collected and classified data on employment of managers and employees (white collars), and laborers and apprentices (blue-collars) at the industry level in Italy and Germany. This distinction between workers follows their occupation classification. These series allowed us to examine how the employment of types of labor changed over time. The adoption of this classification is in line with what is done in most of the existing empirical work, which uses the ratio of production to non-production workers or white-collars to blue-collars as an index of skill intensity in production. This same literature also acknowledges that changes in the ratio of non-production and production workers are an incomplete representation of changes in skill intensity in production because skill upgrading might occur both for production and non-production workers, and type of occupation and skill endowment are only imperfectly correlated. But when working at the industry level, data availability imposes this classification. This is a crude distinction also with respect to the present analysis, as ideally to see the effects of fragmentation on employment composition we would need a much finer classification, distinguishing employees by phases of production (e.g. products' blueprints and design, production of parts, assembly, packaging, distribution…). Unfortunately, also for the countries examined, the white/blue collars classification based on the worker's occupation is the best available matching the distinction in terms of phases of production kept at home and delocalized abroad that characterizes fragmentation processes.

3.2 The weight of international fragmentation of production

During the 1990s, the weight of trade linked to international fragmentation over total trade flows and domestic production in Europe showed an upward trend, even if the extent of the phenomenon is quite different between sectors. Between 1988 and the mid-90s, the share of registered EU re-imports (imports of goods previously temporarily exported to be processed) over 'normal' imports of goods doubled, arriving at 2.7%. The overall figure is not very high, but OPT appears to be concentrated in a few specific sectors. The convenience to delocalize production phases is determined by the product's characteristics and technology. Therefore, only in some industries is production extensively delocalized.

[Figures 2 and 3 about here]

On average, Germany shows a higher propensity to use IFP than Italy: for the entire manufacturing sector, the ratio of OPT re-imports over domestic production is 1.5% in Germany and 0.7% in Italy. Both for Germany and Italy, we can observe basically two groups of sectors where international fragmentation has a relevant weight over total production. There is a group of so-called traditional sectors (namely textiles, apparel, shoes and to a smaller extent furniture), where production phases have become increasingly diversified in terms of factor intensity, and for which unskilled labor is the main factor of production in at least one phase. These are the sectors most subject to international fragmentation. In Germany, the practice to process abroad a large share of apparel production started more than a decade ago, and re-imports of apparel goods amounted to more than 25% of domestic production in 1996, i.e. more than a quarter of German apparel goods was processed abroad. In Italy, the apparel sector is also the most affected, even if to a much smaller extent. In both countries, over time it is possible to observe an increase in the use of OPT in a number of sectors, with the particularly evident case of the apparel industry (code 18). For Italy, upward trends in the relevance of OPT characterize also textiles (code 17) and footwear (code 19), while in Germany this last industry has reduced OPT.

[Figures 4 and 5 about here]

The second group for which OPT is relevant is composed of relatively advanced industries: office machinery, communication equipment, precision instruments and transport equipment. The reasons pushing IFP in these industries are probably different than in the traditional sectors. Here too, some production phases – such as assembly – have become increasingly standardized and more intensive in unskilled labor. But in these advanced sectors fragmentation could also be driven by different technological advantages of countries and by technological inter-linkages, rather than by factor cost differentials. In both Italy and Germany, the communication equipment industry is the most involved in the use of IFP within this second group, showing an increasing trend in OPT until the mid-1990s, but a slowdown of this type of trade in the last year of the sample.

The existence of dissimilarities between IFP in different industries is confirmed by looking at the geographical origin of OPT flows. In figures 2 and 3 we considered separately OPT with the CEECs and the countries located on the southern shore of the Mediterranean basin. These countries display a number of characteristics that make them a favorable location for some production phases: they are geographically close to the EU, reducing transport and coordination costs, and they are characterized by labor abundance and low labor costs relative to the EU. Furthermore, trade agreements with the CEECs and with some Mediterranean countries reduced barriers between them and the EU. Indeed, most of OPT in textiles, apparel, footwear and

furniture takes place in the CEECs and the countries of the Mediterranean basin. The share of this group of countries in Italian and German OPT is quite high also in the electrical machinery industry (where the assembly phases are low-skill-intensive), but it is instead very small in the advanced industries more involved in IFP, such as communication equipment.

It is also interesting to observe that in the last decade there has been a reorientation of Italian and German OPT – especially in traditional industries – toward the CEECs and the Balkans, at the expense first of all of the Mediterranean countries. This reorientation indicates that IFP location is not determined uniquely by wage differentials. During the 1990s, wages in most of the CEECs became higher than wages in the Mediterranean Basin, which therefore should still be preferred as a location for delocalization if we were to consider only this variable.[9] The observation is relevant, because if wage differentials are not the only reason behind IFP, this can affect the impact of IFP on the labor market.

[Figures 6 and 7 about here]

3.3 The change in skill intensity

A number of studies show that in many countries in the past two decades there has been a shift in labor demand toward higher skill-intensity. This occurred not only because of the increasing weight of technology-intensive sectors in manufacturing and of advanced services in the tertiary sector, but especially because within a number of industries production became more skill-intensive (Berman *et al.*,1994; Strauss-Kahn, 2002). Data show that Italy and Germany are no exception in this respect, showing a tendency to increase the skilled-to-unskilled ratio in their working force both at the aggregate and at the industry level.[10]

Germany for the entire manufacturing sector has a slightly higher white-to-blue collar ratio than Italy, but in both countries we could observe a similar upward trend. The ratio increased by approximately 21% in the German and Italian manufacturing industry over the observation period, as a result of the small reduction in blue collars employment and the stronger increase of white collar employment.

Such upward tendency is common to most sectors, with a few exceptions in both countries, displaying a small decline in skill intensity during the observation period. These are office machinery, electrical machinery and motor vehicles in Italy and basic metals and office

[9] Other important variables in choosing the outsourcing location can be distance, promptness in delivery and flexibility in the organization of production. See Evans and Harrigan (2003).
[10] On the changes in the use of skilled and unskilled labor in Italian manufacturing, see also Brenton and Pinna (2001).

machinery in Germany. In these advanced sectors, the decline of the ratio of skilled/unskilled workers seems due to the general shrinking of employment in the industry, which expelled both types of workers, but relatively more white collars. In contrast, the upward trend is evident not only in high-tech sectors such as telecommunication equipment and aircraft equipment, but also in very traditional sectors, such as apparel and furniture, very much subject to a transformation in their production process, transformation that includes the use of OPT.

[Figures 8 and 9 about here]

The sectors most affected by IFP toward low-wage areas (textile, apparel and footwear) can be considered unskilled-labor intensive industries, as the ratio of skilled over unskilled workers is lower than the average ratio for the manufacturing industries. This is especially true for Italy. In Italy, in spite of the clear upward trend in skilled labor employment, the apparel and footwear industries still display a skilled/unskilled ratio that is half the average of the manufacturing sector. The increase in the skilled/unskilled ratio in the apparel sector is due to a decrease in blue-collar employment together with an increase in white-collar. In the footwear industry, the decline in blue collars is not particularly significant, while there is a sharp increase in skilled employment.

In Germany, the variation in skill intensity experienced by the apparel sector is very strong, while this is not the case for the textile and footwear industries in the observed time span. In this industry, as well as in the textile and in the footwear industries, the increase of the ratio is especially due to the reduction of blue-collar employment. The German apparel industry, which started to delocalize abroad segments of production nearly twenty years ago, is currently much more skill intensive than the Italian one, which started to use IFP much more recently and to a much smaller extent. These traditional industries in Germany are now much closer to the manufacturing sector average (which is approximately 0.5 in the mid-1990s) in terms of skilled/unskilled employment.

[Figures 10 and 11 about here]

4. Econometric analysis

4.1 Correlation between international fragmentation of production and skill-intensity

As discussed in section 2, we expect international fragmentation to change the skill-intensity of the production phases taking place domestically, as we can see IFP as a particular type of non-neutral technological change. But the effect of IFP on labor demand depends crucially on the characteristics of the sectors involved. Therefore, as a preliminary assessment of the characteristics of the involved sectors, we estimate the correlation between skill-intensity of each industry and the ratio of OPT over production.

For Italy there is a positive correlation over time between the increase in skill intensity and the relevance of OPT in output production, but across industries such correlation is not significant. In the case of Germany, the correlation over time between skill intensity and relevance of OPT is not very robust for the entire manufacturing sector, but it becomes strongly significant when considering the traditional sectors only. Also in this case, the correlation between skill-intensity and OPT disappears across industries.

From these preliminary results, it is impossible to conclude whether in general more skill-intensive or less-skill intensive sectors are more likely to use OPT, confirming the visual impression gathered through figures 2 and 3 that different industry types can adopt this practice.

4.2 Estimates of the impact of fragmentation on relative skill intensity

To examine the impact of IFP on relative factor demands, it seems appropriate to estimate a function that shows how the access to this organization of production has affected firms' choices. The recent literature aiming at estimating the role of international trade and international outsourcing on relative wages and labor demand, uses a quasi-fixed translog cost function (Brown and Christensen, 1981) with two variable factors, skilled and unskilled labor, and capital as a quasi-fixed factor, with the following general expression:

$$\ln C = \alpha_0 + \sum_{i=1}^{I} \alpha_i \ln w_i + \sum_{k=1}^{K} \beta_k \ln x_k + \frac{1}{2} \sum_{i=1}^{I} \sum_{j=1}^{I} \gamma_{ij} \ln w_i \ln w_j + \\ + \frac{1}{2} \sum_{k=1}^{K} \sum_{l=1}^{K} \delta_{kl} \ln x_k \ln x_l + \sum_{i=1}^{I} \sum_{k=1}^{K} \phi_{ik} \ln w_i \ln x_k \qquad [1]$$

where C represents production costs, w_i denotes the prices of the optimally chosen variable inputs and x_k denotes either the quantities of the fixed inputs or any other shift parameters.

Imposing cost minimization and some parameter restrictions to make the function linearly homogeneous in factor prices generates the factor share equations that are usually estimated. In the literature some papers estimate these cost share equations (see for example, Feenstra and Hanson 1996, 1999 for the US; Gorg *et. al*., 2001, for UK; Hansson, 2001, for Sweden). Another branch of the literature (see for example Brenton and Pinna, 2001, for Italy; Strauss-Kahn, 2002, for France; Anderton et al., 2001, for Sweden; and Egger et al. 2001, for Austria) has estimated employment share equations, which can be derived from the above expression making some additional assumptions.[11] In this paper we adopt the latter approach, and following Feenstra and Hanson' s (2001) suggestion, we introduce an index of IFP as a shift variable in the following skilled employment share equation:

$$S_{it} = \beta_0 + \mu_i + \lambda_t + \beta_1 F_{it} + \beta_2 Y_{it} + \beta_3 (K_{it}/Y_{it}) + \beta_4 (W_{sk}/W_{unsk}) + \varepsilon_{it} \qquad [2]$$

where S is the ratio of skilled and unskilled workers employed in industry i at time t, K is the net capital stock of industry i, Y is gross output of industry i, F is our fragmentation index (re-imports over gross domestic output), W is the wage rate, and μ_i and λ_t are group specific (industry and time, respectively) fixed effects.[12] Logarithmic transformation has been applied to all variables. We estimate equation 2 in levels[13] across industries and time, and adopt a dynamic specification via the introduction in [2] of the lagged dependent variable[14]. This specification allows us to preserve the information contained in the levels of the variables while taking into account the dynamics of the phenomenon.

Results are presented in Table 1 for the dynamic version of Equation 2 with the restriction that $\beta_4 = 0$.[15] We have adopted a two-way fixed effects specification. The presence of the lagged dependent variable generates inconsistency of the within estimator (or least square dummy variable estimator – LSDV) for large N (number of sectors) and small T (number of years). The usual solution in this case is to adopt some kind of generalized method of moments (GMM) estimator. Our empirical set up, however, is one in which both N and T are small of the same magnitude. The small sample properties of the various estimators have not yet been

[11] See Haskel and Slaughter (2002).
[12] See the appendix for the exact definition of variables.
[13] Differently from most other studies that take first differences of the variables and similarly to Görg et al. (2001).
[14] As a matter of comparison with previous literature results for the static specification are reported in the Appendix.
[15] This is a common practice in this literature. It is based on an assumption of perfect inter-industry labour mobility that would induce no cross-sectional wage variation: under this assumption the relative wage variable can be dropped and its effect is captured by the constant term (see Berman et al., 1994). In our case we have also estimated [2] with the relative wage term included, with no substantial difference in the results (see Table A.4).

examined. For this reason, we produce results of both the two-way LSDV estimator and for the Arellano-Bond GMM estimator.

The results are reported in columns 1 and 2 for Italy and columns 3 and 4 for Germany.[16] The significance of sector and time fixed effects is confirmed by the F-tests reported at the bottom of the table. In the estimates for Italy, the coefficient of the index of fragmentation is significantly positive. This positive sign is in line with our expectations, and tends to confirm our hypothesis that the Italian manufacturing sectors use fragmentation of production first of all to delocalize abroad those phases of production that are relatively less skill-intensive. Therefore, in those industries the employment share of skilled labor tends to increase.

The sign of the capital intensity variable in this equation is negative and significant. A priori, the sign of this variable was uncertain, as it would depend on the complementarity or substitutability between capital and skilled labor as production factors. Estimates of a similar equation for other countries show sometimes a positive sign and sometimes a negative sign for the capital variable (see for example Strauss-Kahn, 2002 for the case of France).[17] In the Italian case, the negative sign indicates substitutability between capital and skills. Also the production variable is negative and significant. This variable controls for the scale of production and its sign indicates that as the production scale increases, the employment of blue collars increases more rapidly than the increase of white collars.[18]

Table 1 - Regression results for skilled employment share

	Eq 1.1 Italy	Eq 1.2 Italy	Eq 1.3 Germany	Eq 1.4 Germany
	LSDV2	GMM-AB	LSDV2	GMM-AB
LnF	0.01 (0.004)**	0.01 (0.002)**	0.004 (0.01)	0.02 (0.02)
ln(K/Y)	-0.25 (0.10)**	-0.25 (0.10)**	0.78 (0.32)**	0.53 (0.52)
LnY	-0.46 (0.18)**	-0.46 (0.14)**	0.64 (0.38)*	0.12 (0.67)
lnS(-1)	0.18 (0.13)	0.14 (0.19)	0.49 (0.22)**	0.77 (0.31)**
No. of observations	117	104	80	60

[16] As a matter of comparison, we also report in table A.2 OLS estimates for the specification with no fixed effects and with only sector fixed effects.

[17] Results on the capital variable should be interpreted with caution because ideally one should use data on capital utilization rather than capital stock in this production function, but such data are not available.

[18] Results for these control variables are in line with the results obtained by Brenton and Pinna (2001) for the Italian case.

No. of sectors	13	13	20	20
R-squared	0.72		0.56	
F-test for time effects (p-value)	2.98** (0.005)		1.78 (0.16)	
F-test for sector effects (p-value)	6.42** (0.00)		2.95** (0.00)	
ABII (p-value)		-0.92 (0.36)		-0.32 (0.75)

Note: heteroskedastic robust standard errors in parentheses. Coefficients with a **, * are significant at the 5% and 10% level, respectively.
ABII: Arellano-Bond test for H_0: no second order correlation in the residuals

For Italy, the results are robust across estimators. Results for the fragmentation variable are also relatively robust with respect to the consideration of fixed effects (see Tables A1 and A2). In contrast, the results for the output variable and the capital to output ratio are very sensitive to the inclusion of time dummies (Table A2). It is plausible that results in column 2 (POLS with no fixed effects) suffer from an omitted variable bias due to the lack of a relative wage variable. Controlling for time effects in column 1 should eliminate the bias on the reasonable assumption that relative wage is constant across sectors.

Results are quite different for Germany. The coefficient of the index of fragmentation is not significant, while the capital intensity and the scale variable have positive and significant coefficient. This difference in the control variables with respect to the Italian case seems to indicate that the characteristics of the production process in the two countries are not at all the same. For example, it turns out that capital is complementary to skilled labor.[19] The non significance of the fragmentation index might be due to the fact that Germany in the years of our sample has already achieved the change in the organization of production and the shift in relative labor demand in its traditional sectors, as German firms started to delocalize phases of production abroad almost ten years before the Italian ones. Therefore, our data do not show the relation between IFP and change in the skill intensity probably because the largest part of these changes occurred earlier.

Similarly to other works, we introduce in our regression also an industry-specific R&D index as a proxy of the technological change that might be going on in the industry, shifting the labor demand equation (Table 2). The addition of this variable does not change the results for Italy and the R&D variable itself turns out to be non-significant. In the case of Germany, the introduction of this variable produces some change in the LSDV estimates, but no change in the GMM-AB ones. The R&D coefficient instead is positive and significant. Therefore, in the German case, technological progress seems to be saving unskilled labor and complementary to skilled labor, as is usually expected.

[19] Similar results are obtained by Görg et al. (2001) for UK and by Anderton et al. (2001) for Sweden.

As a test of the robustness of our results, for Italy we also estimated the other specification derived from the translog cost function, that is the cost share equation (Table 3).[20] The results are in line with our expectation, given the results in Table 1. All the control variables maintain signs and significance, and in particular the coefficient of the fragmentation index remains positive and significant. Not surprisingly, in this specification the relative wage variable is always positive and significant when introduced.

Table 2 - Regression results for skilled employment share: with R&D

	Eq 2.1 Italy	Eq 2.2 Italy	Eq 2.3 Germany	Eq 2.4 Germany
	LSDV2	GMM-AB	LSDV2	GMM-AB
lnF	0.009 (0.004)**	0.006 (0.002)**	-0.002 (0.01)	0.01 (0.02)
ln(K/Y)	-0.24 (0.10)**	-0.24 (0.12)*	0.67 (0.33)**	0.25 (0.53)
lnY	-0.47 (0.18)**	-0.48 (0.14)**	0.63 (0.39)	0.02 (0.62)
ln R&D	0.003 (0.008)	-0.007 (0.01)	0.11 (0.05)**	0.19 (0.09)**
lnS(-1)	0.16 (0.14)	0.12 (0.20)	0.47 (0.22)**	0.77 (0.26)**
No. of obs.	108	96	80	60
No. of sectors	12	12	20	20
R-squared	0.72		0.58	
F-test for time effects (p-value)	2.57 (0.01)		5.7 (0.00)	
F-test for sector effects (p-value)	4.40 (0.00)		1.90 (0.14)	
ABII (p-value)		-1.02 (0.31)		0.11 (0.91)

Note: see Table 1

[20] Lack of data prevented us from replicating this exercise for Germany.

Table 3 - Regression results for cost share specification

(dependent variable: log of cost share of skilled labour in the total wage bill – CS)

	Eq. 3.1 Italy	Eq. 3.2 Italy	Eq. 3.3 Italy	Eq. 3.4 Italy
	LSDV2	LSDV2	LSDV2	GMM-AB
LnF	0.005 (0.004)	0.005* (0.003)	0.01** (0.004)	0.01** (0.001)
Ln(K/Y)	-0.22 (0.15)	-0.26** (0.09)	-0.28** (0.10)	-0.25** (0.12)
LnY	-0.64** (0.24)	-0.60** (0.16)	-0.51** (0.17)	-0.41** (0.19)
ln(wsk/wunsk)		1.07** (0.16)	0.95** (0.17)	0.97** (0.09)
LnCS(-1)			0.12 (0.10)	0.03 (0.11)
No. of observations	130	130	117	104
No. of sectors	13	13	13	13
R-squared	0.68	0.85	0.83	
F-test for time effects (p-value)	8.90 (0.00)	9.27 (0.00)	3.93 (0.00)	
F-test for sector effects (p-value)	1393.5 (0.00)	2643.5 (0.00)	10.68 (0.00)	
ABII (p-value)				-0.86 (0.39)

Note: heteroskedastic robust standard errors in parentheses
Coefficients with a **, * are significant at the 5% and 10 level.
ABII: Arellano-Bond test for H_0:(no second order correlation in the residuals)

5. Conclusions

In this paper we analyzed the labor market effects of international fragmentation of production in Europe. Because of its characteristics, IFP is a form of organization of production very likely to be factor biased and therefore we expect it to affect relative labor demand. In particular, we wanted to test if the shift toward skilled labor observed in Italy and in Germany is related to the fragmentation activity undertaken by a large number of firms, especially in industries traditionally considered intensive in unskilled labor.

In our estimates of the equation measuring the shifts of the labor demand function, the index of international fragmentation of production is consistently positive and significant for Italy, showing that part of the increase in the skilled-to-unskilled labor ratio in Italy is linked to this form of organization of production. This result is especially relevant because we use a strictly defined measure of IFP that should capture specifically firms' decisions pertaining to the re-organization of production and their demand for labor. Instead, in the case of Germany we never found a significant impact of IFP on the relative demand for skilled labor.

These contradictory results might appear puzzling, but they are very much in line with the predictions of the theory. International fragmentation of production has different characteristics in Italy and in Germany, the latter being involved in this practice earlier and to a larger extent than Italy. Changes occurred in the past that might have affected the present organisation of production in Germany, which is currently more skill-intensive than Italian production. As the industries most affected by IFP in Germany have a skilled/unskilled ratio much closer to the national manufacturing average, changes in those industries on average do not have a strong impact on labor demand. In Italy, where the change is ongoing in industries further away from the average of manufacturing, the impact appears stronger.

Recent studies undertaken on IFP in countries different than the ones considered here sometimes confirm the relationship between IFP and relative labor demand, but sometimes do not. The heterogeneity of empirical results observed here and elsewhere is not surprising. Theoretical models show that the net effect of IFP on the labor market depends upon which phases of production are delocalised, in which industries and toward which countries delocalization takes place, and on how this will affect the overall composition of output. This implies that even in advanced, skill-abundant countries, IFP will not necessarily widen inequalities between workers.

Appendix A – Robustness checks

Table A1 - Regression results for skilled employment share: static specification

	Eq A1.1 Italy	Eq A1.2 Italy	Eq A1.3 Germany	Eq A1.4 Germany
	LSDV2	LSDV2	LSDV2	LSDV2
lnF	0.005 (0.003)*	0.005 (0.003)*	-0.02 (0.03)	-0.02 (0.03)
ln(K/Y)	-0.26 (0.09)**	-0.22 (0.10)**	1.52 (0.51)**	1.37 (0.50)**
lnY	-0.60 (0.15)**	-0.58 (0.16)**	1.29 (0.50)**	1.23 (0.50)**
ln R&D		-0.003 (0.01)		0.08 (0.04)*
No. of observations	130	120	100	100
No. of sectors	13	12	20	20
R-squared	0.74	0.74	0.42	0.44
F-test for time effects (p-value)	10.1 (0.00)	7.9 (0.00)	5.7 (0.00)	5.8 (0.00)
F-test for sector effects (p-value)	2602.7 (0.00)	2401.6 (0.00)	387.6 (0.00)	193.3 (0.00)

Note: heteroskedastic robust standard errors in parentheses. Coefficients with a **, * are significant at the 5% and 10% level, respectively.

Table A2 - Regression results for skilled employment share: static - no heterogeneity and industry fixed effects

	Eq A2.1 Italy	Eq A2.2 Italy	Eq A2.3 Germany	Eq A2.4 Germany
	LSDV1	POLS	LSDV1	POLS
const	-4.56 (0.78)**	-14.17 (2.72)**	-13.28 (4.60)	-2.54 (3.16)
lnF	0.14 (0.003)**	-0.05 (0.01)**	0.01 (0.01)	-0.01 (0.02)
ln(K/Y)	0.23 (0.08)**	0.33 (0.09)**	1.43 (0.75)*	0.00 (0.07)
lnY	0.40 (0.09)**	2.44 (0.58)**	1.02 (0.68)	0.42 (0.63)
No. of observations	130	130	100	100
No. of sectors	13	13	20	20
R-squared	0.47	0.24	0.17	0.01
F-test for sector effects (p-value)	1117.6 (0.00)		93.3 (0.00)	

Note: see Table A1

Table A3 - Regression results for skill intensity: dynamic - no heterogeneity and industry fixed effects

	Eq A3.1 Italy	Eq A3.2 Italy	Eq A3.3. Germany	Eq A3.4 Germany
	LSDV1	GMM-AB	LSDV1	GMM-AB
const	-0.31 (0.89)	0.54 (0.23)**	-5.75 (4.27)	0.79 (0.53)
lnF	0.01 (0.004)**	-0.001 (0.002)	0.01 (0.01)	-0.01 (0.01)
ln(K/Y)	-0.02 (0.09)	-0.01 (0.01)	0.65 (0.42)	-0.03 (0.01)**
lnY	-0.05 (0.08)	-0.11 (0.51)**	0.37 (0.44)	-0.14 (0.11)
lnS(-1)	0.52 (0.10)**	1.00 (0.01)**	0.56 (0.22)**	0.99 (0.02)**
No. of observations	117	117	80	80
No. of sectors	13	13	20	20
R-squared	0.63	0.99	0.48	0.96
F-test for sector effects (p-value)	4.52** (0.00)		2.81** (0.00)	

Note: see Table A1

Table A4 - Regression results for skill intensity: dynamic specification with relative wage

	Eq A4.1 Italy	Eq A4.2 Italy	Eq A4.3 Germany	Eq A4.4. Germany
	LSDV2	GMM-AB	LSDV2	GMM-AB
lnF	0.01 (0.004)**	0.01 (0.002)**	0.004 (0.01)	0.02 (0.02)
ln(K/Y)	-0.24 (0.10)**	-0.25 (0.10)**	0.78 (0.32)**	0.53 (0.52)
lnY	-0.46 (0.18)**	-0.47 (0.14)**	0.64 (0.38)*	0.12 (0.67)
Ln(Wsk/Wunsk)	-0.05 (0.16)	-0.04 (0.48)		
lnS(-1)	0.18 (0.13)	0.14 (0.19)	0.49 (0.22)**	0.77 (0.31)**
No. of observations	117	104	80	60
No. of sectors	13	13	20	20
R-squared	0.72		0.56	
F-test for time effects (p-value)	3.81** (0.00)		1.78 (0.16)	
F-test for sector effects (p-value)	6.34** (0.00)		2.95** (0.00)	
AB II (p-value)		-0.92 (0.36)		-0.32 (0.75)

Note: see Table A1

Appendix B – Data and Sources

The empirical analysis in this paper was undertaken on 20 manufacturing sectors classified according to the International Standard Industrial Classification of all economic activities (ISIC), Third Revision.

The industry codes and definitions of the considered sectors are the following:

17 Manufacture of textiles
18 Manufacture of wearing apparel; dressing and dyeing of fur
19 Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
20 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
21 Manufacture of paper and paper products
22 Publishing, printing and reproduction of recorded media
23 Manufacture of coke, refined petroleum products and nuclear fuel
24 Manufacture of chemicals and chemical products
25 Manufacture of rubber and plastic products
26 Manufacture of other non-metallic mineral products
27 Manufacture of basic metals
28 Manufacture of fabricated metal products, except machinery and equipment
29 Manufacture of machinery and equipment NEC (not elsewhere classified)
30 Manufacture of office, accounting and computing machinery
31 Manufacture of electrical machinery and apparatus NEC
32 Manufacture of radio, television and communication equipment and apparatus
33 Manufacture of medical, precision and optical instruments, watches and clocks
34 Manufacture of motor vehicles, trailers and semi-trailers
35 Manufacture of other transport equipment
36 Manufacture of furniture; manufacturing not elsewhere classified.

Variables definition and sources:

OPT: outward processing trade (temporary exports and re-imports) at current prices, from Eurostat, Comext database. Eurostat outward processing trade (OPT) is recorded only for extra-EU trade. Therefore, in the geographical disaggregation of trade flows, "total" refers to flows between the considered EU country (Italy or Germany here) and all the non-EU countries.
"MedaEst" indicates a group of countries geographically close to the EU whose wages are much below the EU average. In our classification these countries are: Bulgaria, Czech Republic, Estonia, Lithuania, Latvia, Romania, Poland, Slovakia, Hungary, Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Albania, Algeria, Bosnia, Croatia, Cyprus, Egypt, Gaza, Israel, Lebanon, Libya, Jordan, Macedonia, Morocco, Slovenia, Syria, Tunisia, Turkey, Yugoslavia.
Prod: industrial production at current prices. The sources were *Conti economici delle imprese*, Istat and *Structural statistics for industry and services vol.1*, OECD for Italy; *Industrial Structural Statistics*, OECD for Germany.
The **index of fragmentation** (F) was calculated as the ratio of re-imports of industry j over domestic production of industry j (OPT/Prod).

Skill: number of managers and white-collar workers. The sources were *Conti economici delle imprese*, Istat for Italy and *Produzierendes Gewerbe, Fachserie 4, Reihe 4.3*, Statistisches Bundesamt for Germany.
Unskill: number of blue-collar workers. The sources were *Conti economici delle imprese*, Istat for Italy and *Produzierendes Gewerbe, Fachserie 4, Reihe 4.3*, Statistisches Bundesamt for Germany.
The **index of skill intensity** (S) was calculated as the ratio of white-collar over blue-collar workers (Skill/Unskill).
K: for Italy: net capital stock at constant prices. The source was OECD, Stan database.
for Germany: gross capital stock at constant prices. The source was OECD, Stan database
Y: for Italy: production at constant prices. The source was OECD, Stan database
for Germany: value added at constant prices. The source was OECD, Stan database

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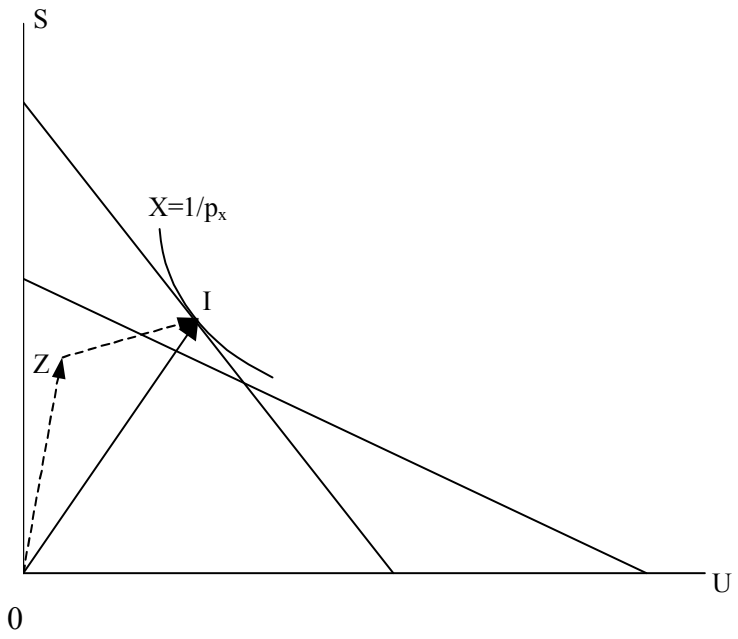
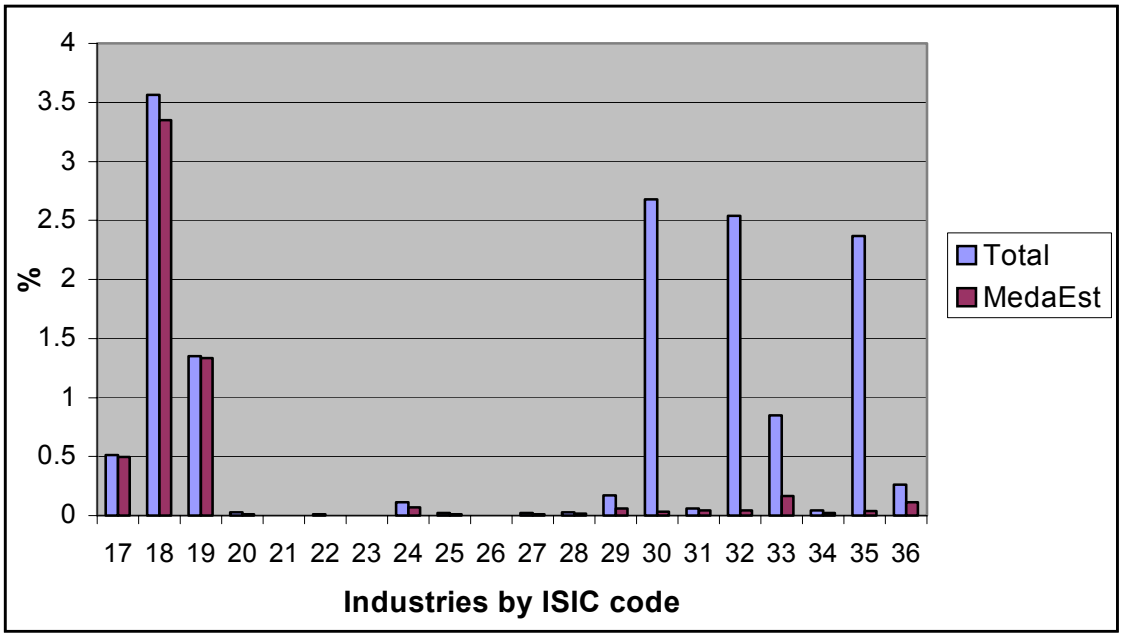
Figure 1 – Impact of fragmentation of production on relative skill intensity in production



Note: Production of good X employing skilled labor (S) and unskilled labor (U). The negatively sloped lines represent relative factor prices in the West (steepest line) and in the East. The continuous arrow represents the integrated production technology, while the broken arrows represent the fragmented technology.

Figure 2 – Italian re-imports over domestic production in 1996



Note: "Total" refers to the ratio of re-imports from all geographical areas over domestic production, while "Meda Est" refers to the ratio of re-imports from countries in the Mediterranean Basin and in Central and Eastern Europe (see Appendix for the exact definition of the area).

Figure 3 – German re-imports over domestic production in 1996

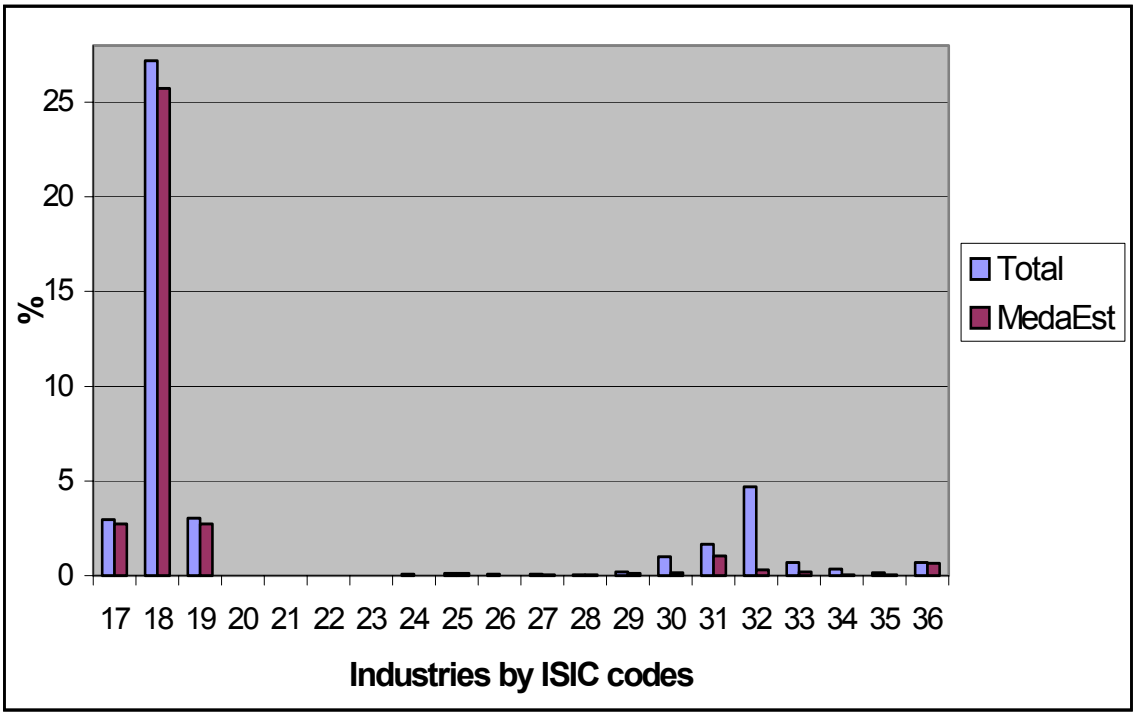


Figure 4 – Italian re-imports over domestic production by industry

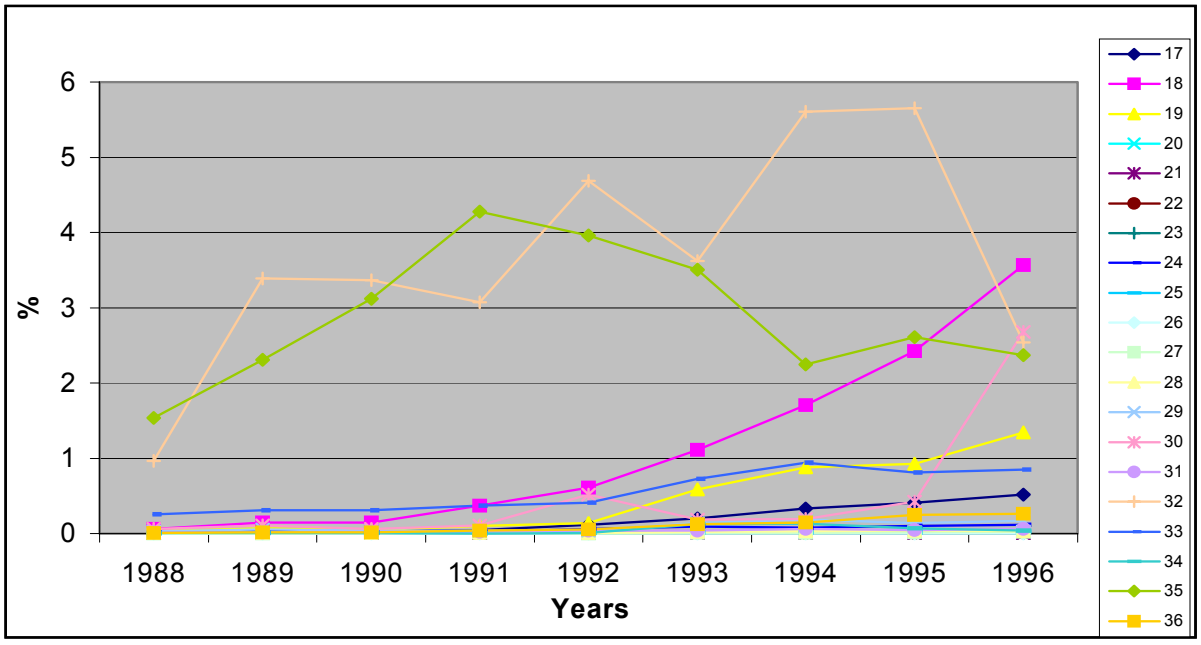


Figure 5 - German re-imports over domestic production by industry

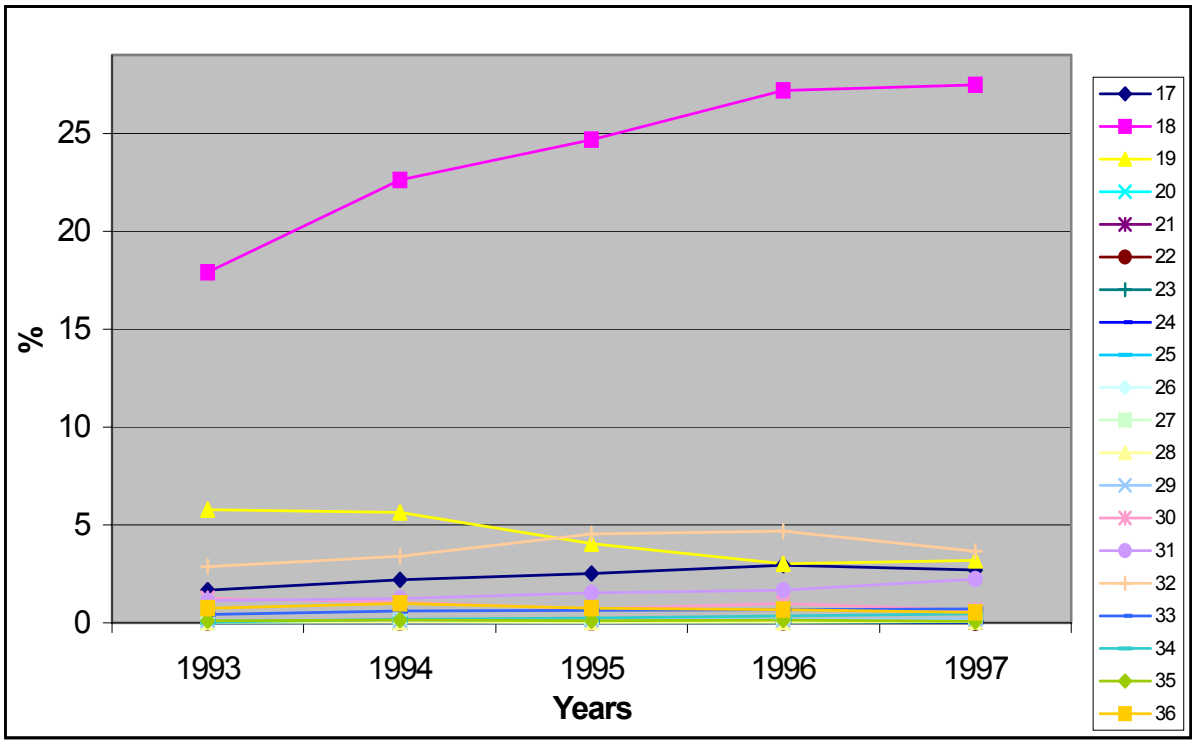
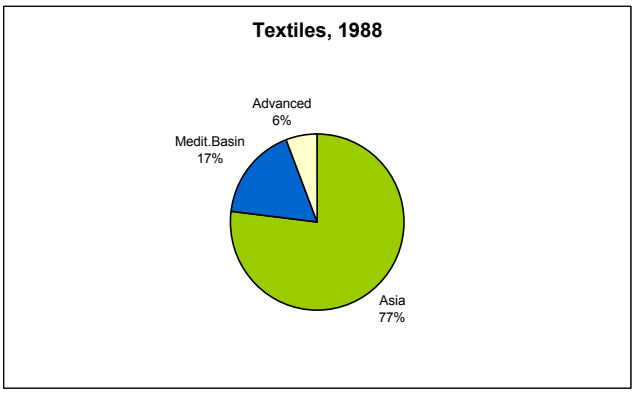
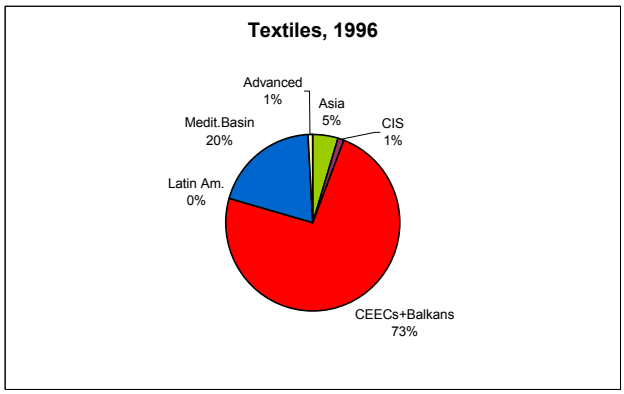
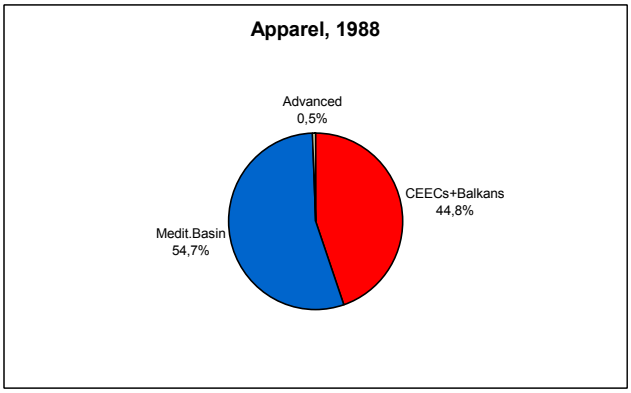
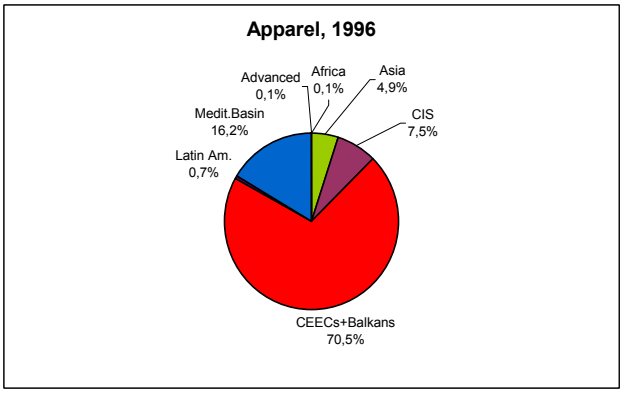


Figure 6 – Geographic composition of Italian re-imports, selected industries









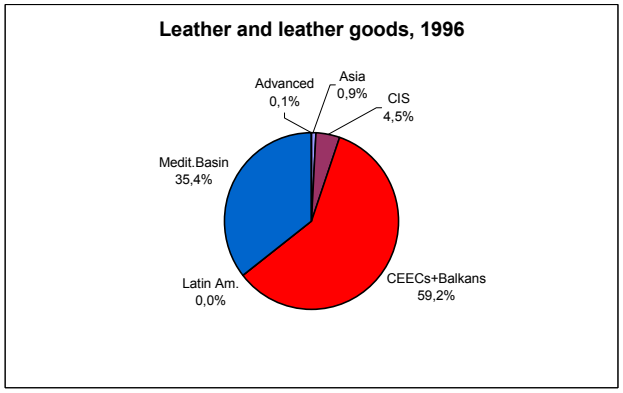


Figure 7 – Geographic composition of German re-imports, selected industries

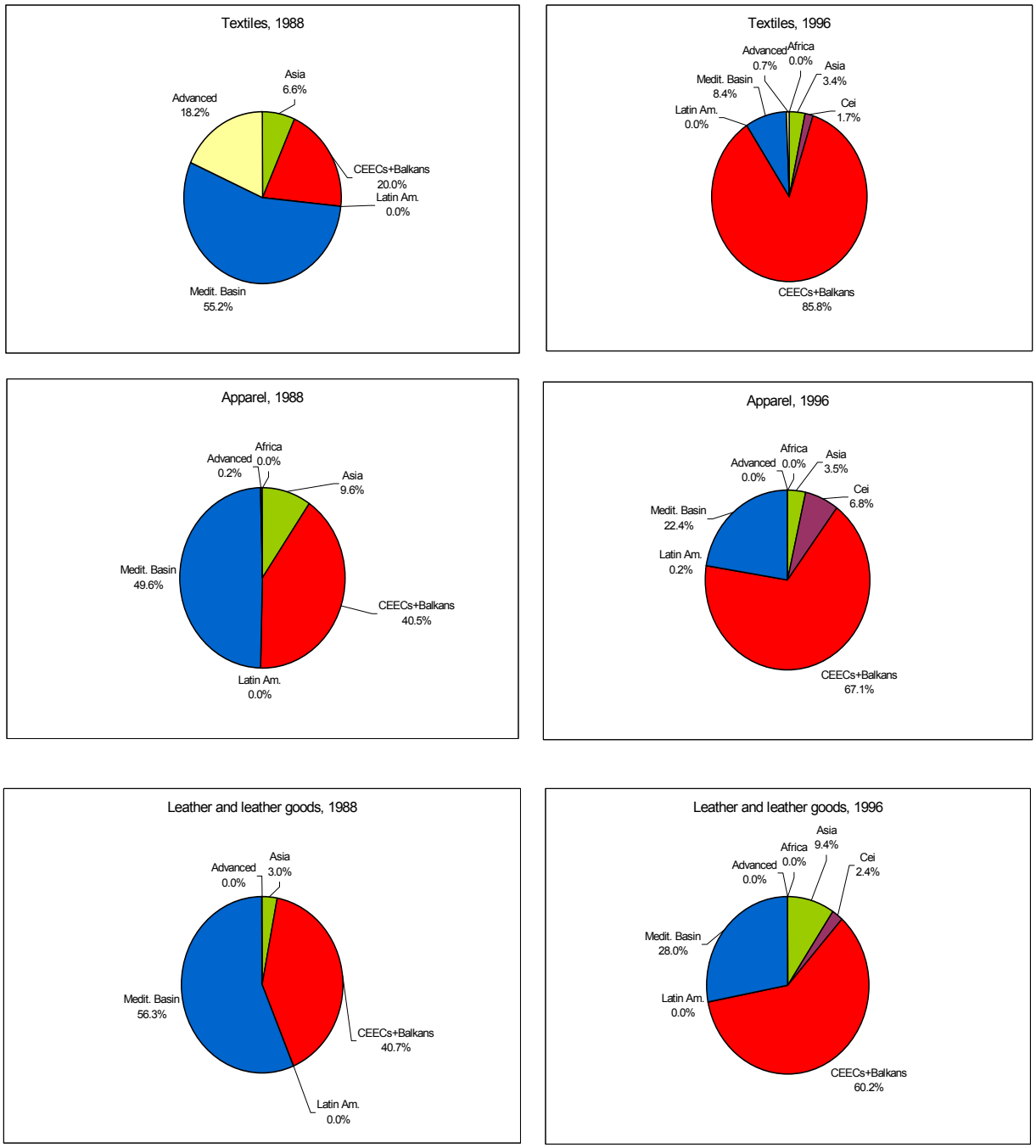


Figure 8 – Relative employment of skilled and unskilled workers in Italy by industry

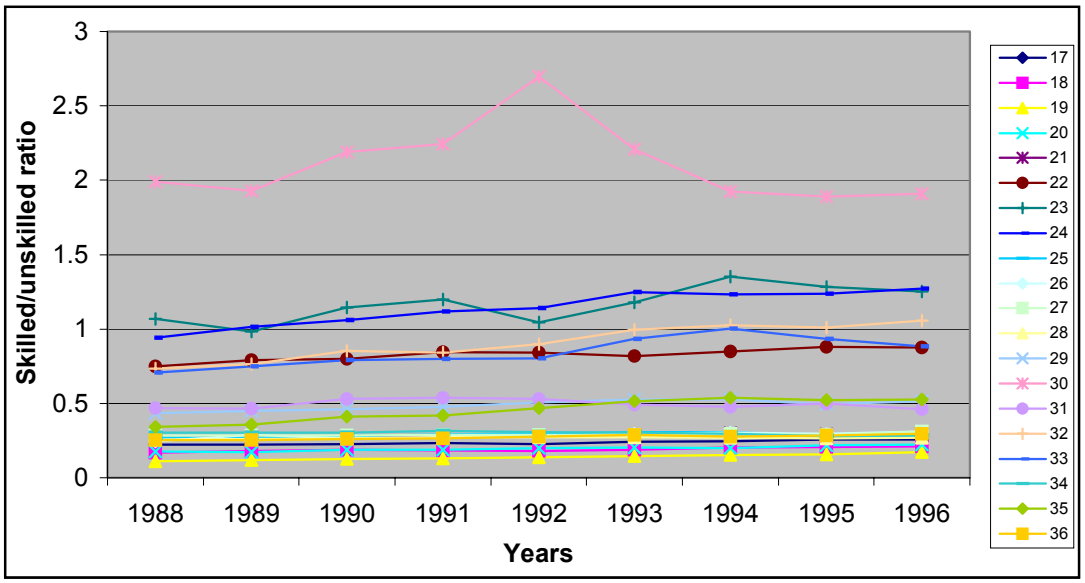


Figure 9 – Relative employment of skilled and unskilled workers in Germany by industry

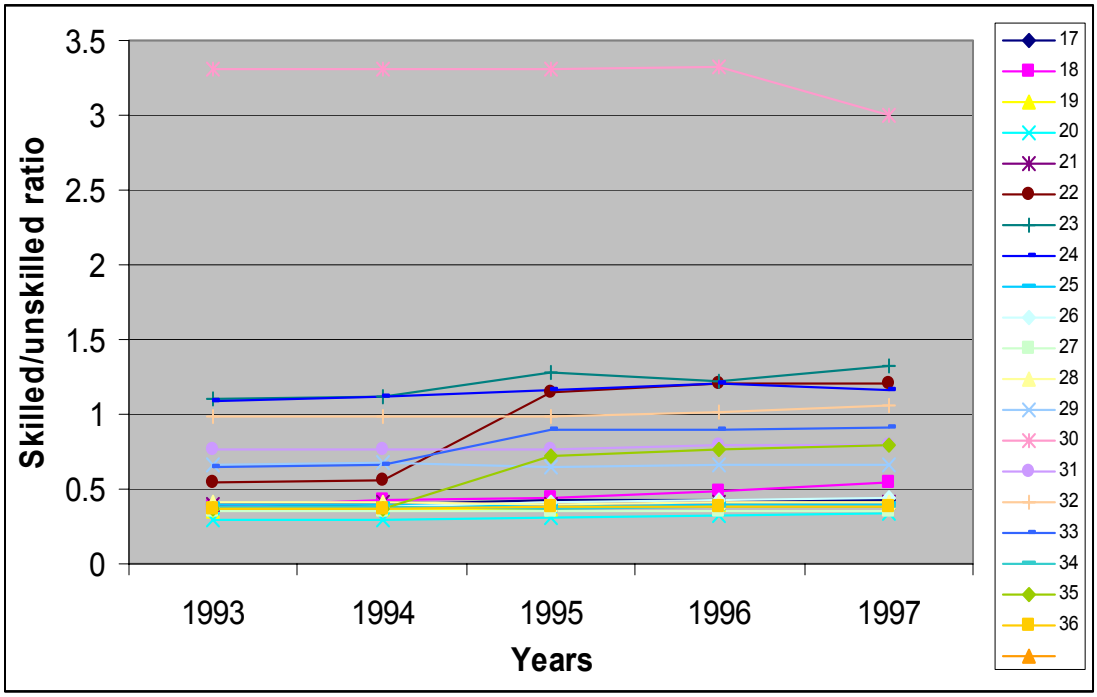


Figure 10 - Relative employment of skilled and unskilled workers in Italy in the industries with the highest fragmentation index toward MedaEst area

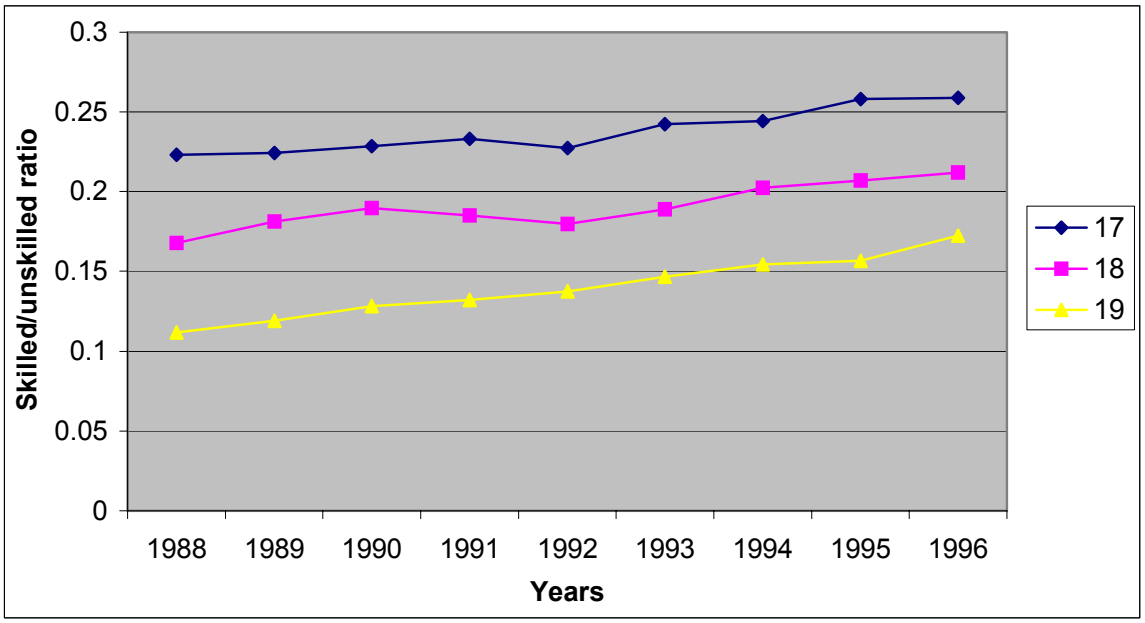


Figure 11 - Relative employment of skilled and unskilled workers in Germany in the industries with the highest fragmentation index toward MedaEst area