

# How Do Industries and Firms Respond to Changes in Local Labour Supply?

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## Abstract

In this paper, we first investigate how industries respond to changes in the skill mix of local labour supply due to immigration. One way to absorb these changes is an expansion in size of those industries that use the corresponding skill group more intensively with fixed relative factor inputs within industries. Alternatively, industries can adjust their production process and switch to a technology that uses the corresponding skill group more intensively. We investigate which of these channels is dominant, distinguishing between tradable and non-tradable industries. We then extend the analysis to the firm level using administrative data on all workers and their skill levels in all firms in Germany between 1985 and 1995. We distinguish between small and large firms as well as permanent and newly established firms. Our findings on the industry level show that changes in relative labour supply are accommodated within, rather than between industries, supporting recent results for the U.S. by Lewis (2004). The breakdown on the firm level suggests that the within industry adjustment is due to within firm technology adjustments, mostly of firms in tradable industries, and that the creation of new firms plays an important role in absorbing changes in relative factor supplies.

**Keywords:** Immigration, Endogenous Technological Change, Firm Structure

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# 1 Introduction

One of the main consequences of immigrant inflows into a labour market is the alteration of the relative supply of workers of different skill levels and the induced change in equilibrium wage and employment rates. A large number of empirical studies have tried to quantify these impacts of immigration on the labour market outcomes of the resident population in a variety of countries using regional variation in immigrant inflows.<sup>1</sup> The majority of these studies have failed to find any significant negative effect of immigration on both relative wages and employment rates. This result is somewhat at odds with the common notion that the labour demand curve is downward sloping and that therefore an increase in labour supply should, in a competitive market, lead to a decrease in wages and, with elastic labour supply, an increase in unemployment. One possible explanation for the apparent insensitivity of local wages to immigration that has been put forward is based on standard trade theory and in particular on the Factor Price Insensitivity Theorem (Leamer and Levinsohn, 1995). Accordingly, as long as there are a number of output goods being produced in a region with different relative factor intensities and as long as these goods are tradable across regions, a change in local relative factor endowments through immigration will not lead to changes in relative factor prices but rather to an adjustment in the output mix of the immigrant-receiving region.<sup>2</sup>

Although some impact studies have pointed towards changes in output mix as a potential adjustment channel to regional immigration (e.g. Card, 1990, 2001, and Friedberg and Hunt, 1995), the actual empirical evidence is scarce. In a recent paper, Ethan Lewis (2004b) has for the first time specifically analysed the extent to which the industry mix in U.S. metropolitan areas adjusts to changes in local factor supplies caused by immigration.<sup>3</sup> In his analysis, he decomposes the change in local factor supplies into a part that is

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<sup>1</sup>See Dustmann and Glitz (2005) for an overview of the literature.

<sup>2</sup>Recent work by Hanson and Slaughter (2002) and Quispe-Agnoli and Zavodny (2002) for the U.S., Davis et al. (1997) for Japan, and Bernhard et al. (2002) for the UK evaluates the validity of the Heckscher-Ohlin-Samuelson theory within countries which underlies this adjustment mechanism.

<sup>3</sup>Gandal et al. (2004) provide a related analysis by investigating how national changes in output mix

absorbed by changes in the scale of industries and a part that is absorbed by changes in the relative factor intensities within industries. His findings suggest that only a small fraction of the changes in local labour supply is accommodated through changes in the industry mix and that most of the adjustment happens through within-industry changes in worker mix. Since there is no evidence of significant changes in relative wages, he concludes that industries are changing their production technologies to complement the changes in local factor supplies, a conclusion also supported by a case study of the industry adjustments in the Miami labour market in the aftermath of the Mariel boatlift (Lewis, 2004a).

The observation that production technologies may change in response to local factor supply conditions has recently been theoretically modeled and empirically tested in the literature. One way such adjustment could come about is through an endogenous choice of the direction of research by profit-maximising innovators so that new technological innovations available to firms are complementary to particular factor supply conditions (see for instance Acemoglu, 1998, 2002). As an alternative to this technology supply explanation, it could be that the demand for technologies is endogenous so that firms optimally decide which technology out of a given pool of available technologies to adopt given the factor supplies they are facing (see Atkinson and Stiglitz, 1969; Basu and Weil, 1998; Beaudry and Green, 2003, 2005; Caselli, 1999; Caselli and Coleman, 2006). Recent empirical evidence that on the job computer use as well as automation expand most rapidly in those areas where the relative supply of skilled labour grows fastest points towards the importance of this demand-side explanation (Beaudry et al., 2006; Doms and Lewis, 2006; Lewis, 2005).

In this paper, we first re-assess the importance of industry mix adjustments in absorb-

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and global changes in production techniques in the form of skill-biased technological change have helped Israel to absorb the large number of Russian immigrants who arrived in the early 1990s. Similar to Lewis (2004b), their results suggest that output mix adjustments did not play a significant role and that changes in production techniques were sufficient to offset the substantial changes in relative factor supplies induced by the immigrant inflows.

ing changes in local factor endowments and compare our findings for Germany with the results found by Lewis (2004b). We distinguish between tradable and non-tradable industries and show which channel, between industry scale or within industry factor intensity adjustments, is dominant in each of these industry types. We then decompose the observed adjustments on the industry level into scale and intensity adjustments on the firm level taking advantage of a unique data set that comprises the entirety of firms that operated in West Germany between 1985 and 1995. We show that an analysis on the industry level does not accurately reflect the changes in employment and factor intensities that take place on the firm level and that conclusions about the importance of endogenous technology changes in response to changes in factor supplies derived from an industry-level analysis have to be drawn with care.

Our empirical results show that adjustments in the output mix as predicted by trade theoretic models do not play a large role in accommodating changes in local factor endowments, even on the firm level. Adjustments in within firm relative factor intensities, by contrast, are important and, given relatively small wage adjustments, point towards the endogenous adoption of new production technologies. However, a large part of what is considered as within industry changes in worker mix stems from the net creation of new firms and cannot necessarily be interpreted as technological change as previously suggested.

The remainder of this paper is structured as follows. In the next section we describe the data we are using for this analysis and provide some descriptive evidence on the industry and firm structure in West Germany between 1985 and 1995. In Section 3 we show the extent to which local relative wage and employment rates have responded to the changes in local factor supplies induced by the immigrant inflows to Germany between 1985 and 1995. In Section 4 we then explain our analytical framework and present our empirical results, first for the industry and then for the firm level analysis. Section 5 analyses to

what extent relative wages within firms have responded to changes in firm-specific factor intensities. Section 6 concludes.

## 2 Data

The data base we are using for our analysis is the entirety of the German social security records which are provided by the Institute for Employment Research (IAB). The data comprises the employment histories of all dependent employees subject to social security contributions in Germany. It includes all wage earners and salaried employees but excludes the self-employed, civil servants, and the military.<sup>4</sup> What is crucial to our analysis is that the social security records for each working individual include an identifier for the firm he or she is working in. We use this identifier to construct a yearly panel of all firms in Germany that includes information about their skill-specific employment and wages, the industry they belong to, and the region they operate in.<sup>5</sup>

The major advantage of using the entirety of individuals in Germany is that we are able to capture all firms in Germany and not only a particular subset thereof. Most firm level datasets such as the Annual Survey of Manufactures for the U.S. are biased towards large establishments. The IABS, a 2% subsample of our data that is publicly available to researchers, also includes a firm identifier variable as well as a set of variables that show the overall employment by skill group for each firm. Based on this data set, it is therefore possible to construct a panel of firms similar to the one we use in this analysis. However, because individuals from large firms are more likely to be included in the IABS, such a

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<sup>4</sup>In 2001, 77.2% of all workers in the German economy were covered by the social security system (Bundesagentur für Arbeit, 2004).

<sup>5</sup>The wage records in the IAB data sample are top coded at the social security contribution ceiling which is particularly severe for individuals in the highest skill group. Across regions, the mean fraction of individuals with censored wage observations is 0.6% for the low-skilled, 5.0% for the medium-skilled, and 41.6% for the high-skilled. Throughout the analysis we therefore use median wages and indicate whenever the median wage remains subject to censoring, i.e. when more than 50% of the observations within skill group are censored. All wages are gross daily wages in real 1995 Euro terms based on the consumer price index for all private households.

firm panel over-represents large firms relative to small firms. In fact, while only 1.9% of firms in Germany had more than 100 employees in 1995, this share of large firms based on the IABS subsample is 14.8%. Since the aim of this paper is to analyse changes in aggregate industry and firm growth as well as firm-level technology adjustments, and the vast majority of firms in Germany is small with 13 employees on average, it would be potentially misleading to only focus on large establishments. Our analysis will show that it is in small firms where most of the adjustments, in particular in relative factor intensities, take place.

The basis of our analysis are all individuals aged 15 to 64 that work full-time. We differentiate skill groups by their educational attainment, distinguishing three groups: low, intermediate and high. People with low education are individuals without an apprenticeship, people with intermediate education are individuals with an apprenticeship and people with high education are individuals with college education. Apprenticeships are a crucial component of Germany's educational system and more than two thirds of all Germans have completed one in 1995. Individuals usually enter apprenticeships immediately after leaving school. They typically consist of two to four years on the job training with complementary class room teaching one day per week. In terms of future income, apprenticeships are a more important determinant than the actual number of years an individual went to school. For instance, the average daily wage of German individuals without an apprenticeship in West Germany in 1995 is €51.5 if they do not have A-levels, and only marginally higher at €52.4 if they do. For that reason, we choose them as the prime indicator of an individual's skill level in terms of educational attainment.

Throughout the analysis we focus on the period 1985 to 1995 during which substantial immigration to Germany took place which led to significant changes in local factor supplies. Basis of our estimations on the industry level are 79 industries in 204 labour market

regions in West Germany.<sup>6</sup> We distinguish between 44 industries that produce tradable goods (=tradable industries) and 35 industries that produce non-tradable goods (=non-tradable industries). Following Hanson and Slaughter (2002), we include the following sectors in the group of tradable industries: manufacturing, agriculture, mining, finance, real estate, business services and legal services. For a detailed overview of the individual industries, their classification as tradable and non-tradable and a number of key indicators see Table A-1 in the appendix. The biggest tradable industry in 1995 was *Manufacturing of electrical equipment* with around 790,000 employees, which corresponded to 4.7% of the overall full-time employment in West Germany in that year. The biggest non-tradable industry was *Retail* with around 2.2 million employees or 13% of the overall employment. Overall full-time employment declined by 4.2% to around 7.8 million in tradable industries and grew by 7.5% to around 8.9 million in non-tradable industries. However, variation in employment growth was substantial, ranging from a decrease of 51.6% in the tradable industry *Manufacture of apparel* to an increase of 103.8% in the non-tradable industry *Other services*. Employment in tradable industries comprised relatively more low-skilled as well as high-skilled workers (24.1% and 8.5% respectively) than employment in non-tradable industries (21.5% and 6.8% respectively). In both tradable and non-tradable industries the use of low-skilled workers declined significantly between 1985 and 1995 by 28.1% and 22.0%, respectively, whereas the use of high-skilled workers increased by 64.3% and 41.8% respectively. Firms were larger in tradable industries with on average 20.5 employees compared to only 9.9 employees in firms operating in non-tradable industries.

Table 1 provides some detailed information on firms in West Germany. Overall there were 1,383,591 firms in West Germany's 204 labour market regions in 1995, 402,452 of

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<sup>6</sup>West Germany's unification with East Germany took place on the 3rd of October 1990 but data on East Germany is only included in the IAB data from 1992 onwards. Therefore we focus exclusively on labour market regions in West Germany. Labour market regions are aggregates of West Germany's 326 counties that take commuter flows into account so that they better reflect separate local labour markets. They comprise around 320,000 individuals on average.

Table 1: Firm characteristics

	1995			% Change 1985 - 1995		
	all	tradable	non-trad.	all	tradable	non-trad.
<u>No. of firms</u>	1,383,591	402,452	981,139	9.4	10.4	9.0
No. permanent firms	685,666	210,680	474,986	.	.	.
No. new firms	697,925	191,772	506,153	.	.	.
No. old firms †	579,241	153,938	425,303	.	.	.
Average size	13.0	20.5	9.9	-5.2	-12.3	1.3
% low skill	22.7	24.1	21.5	-25.6	-28.1	-22.0
% medium skill	69.7	67.4	71.7	8.0	9.9	6.0
% high skill	7.6	8.5	6.8	52.4	64.3	41.7
Wage low skill	57.9	63.9	49.2	16.1	16.7	22.9
Wage medium skill	76.9	83.2	72.5	15.3	14.8	16.4
Wage high skill	128.4	131.1*	118.0	14.0*	15.8*	9.8
<u>No. of small firms</u>	1,359,857	390,428	969,429	9.5	10.8	9.0
No. permanent firms	666,139	200,782	465,357	.	.	.
No. new firms	693,718	189,646	504,072	.	.	.
Average size	7.3	8.9	6.7	7.4	5.6	8.2
% low skill	21.8	21.7	21.9	-24.5	-29.0	-21.7
% medium skill	72.9	71.7	73.6	7.2	8.3	6.5
% high skill	5.3	6.6	4.5	71.8	104.0	52.3
Wage low skill	46.0	50.7	42.3	34.5	31.0	39.6
Wage medium skill	70.2	73.8	68.3	16.1	15.4	16.4
Wage high skill	109.5	115.0	106.0	10.3	7.3	11.5
<u>No. of large firms</u>	23,734	12,024	11,710	1.7	-2.1	5.9
No. permanent firms	19,527	9,898	9,629	.	.	.
No. new firms	4,207	2,126	2,081	.	.	.
Average size	337.5	395.8	277.5	-11.1	-12.2	-7.6
% low skill	23.7	25.8	20.6	-25.9	-26.5	-23.0
% medium skill	65.9	64.4	68.2	7.7	9.6	4.4
% high skill	10.4	9.8	11.2	52.0	58.3	42.3
Wage low skill	66.6	69.6	59.9	16.5	16.7	17.2
Wage medium skill	85.3	89.6	80.1	16.8	16.6	18.3
Wage high skill	131.1*	131.1*	127.7	15.8*	15.8*	13.5*

Notes: Wages are median wages of each skill group. A (\*) indicates that the median wage suffers from right censoring, that is that more than 50% of the individuals in that group had wages above the taxable base so that the table entry is simply the value of the censoring limit in 1995. For the wage changes, a (\*) indicates that in at least one of the years 1985 and 1995, the median wage lay above the taxable base so that the percentage change is not accurate. Large firms are firms with more than 100 full-time employees in 1985.

† The number of old firms refers to the number of firms that existed in 1985 but do not exist anymore in 1995.

those in tradable and 981,139 in non-tradable industries. Roughly half of these firms were permanent firms, that is firms that had already existed in 1985, and half were firms that had been newly established in the ten years between 1985 and 1995.<sup>7</sup> The vast majority

<sup>7</sup>There is some concern in the IAB data with regard to the interpretation of newly occurring firm identifiers. If a firm changes its legal status from say a limited company to a stock corporation, then often this firm would receive a new identifier and would thus appear in our data as a new firm, leading to a higher observed

of firms, 98.3%, were small with overall full-time employment of less than 100 workers and an average size of 7.3 workers. The average size of the 23,734 firms that had more than 100 employees was 337.5, with significantly larger firms in tradable industries with on average 395.8 workers compared to only 277.5 in non-tradable industries. While the average size of firms in tradable industries declined by 12.3% between 1985 and 1995, it increased slightly by 1.3% for firms in non-tradable industries. In terms of relative factor inputs, there was hardly any difference between small firms in tradable and those in non-tradable industries. Around 22% of workers were low-skilled, 72% medium-skilled and 6% high-skilled. In large firms by contrast, those in tradable industries were more low-skill intensive with a worker share of 25.8% than those in non-tradable industries with a share of only 20.6%. Between 1985 and 1995, small firms increased their input of high-skilled workers by 71.8% whereas large firms only increased it by 52.0%. The shift from low- to high-skill employment was particularly pronounced in small firms in tradable industries, where the former decreased by 29.0% and the latter increased by 104%.

There were substantial differences in the wage level between small and large firms across all skill groups. While the median wage for low-, medium- and high-skilled workers in small firms was €46.0, €70.2 and €109.5, respectively, it was €66.6, €85.3 and above the censoring limit of €131.1 in large firms in 1995. Wage growth for low-skilled workers was particularly high in small firms with 34.5% compared to only 16.5% in large firms. Wages grew similarly in large firms in tradable and non-tradable industries but tended to grow faster in small firms in non-tradable industries than in small firms in tradable industries. Overall, wage growth between 1985 and 1995 was quite similar across skill groups with a rate of 16.1% for low-skilled workers and 15.3% for medium-skilled workers.<sup>8</sup> In particular, relative wages in tradable industries did not change much between 1985

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firm turnover. However, it is known that plant turnover is substantial so that the roughly equal numbers of permanent and new firms are not too surprising. For example, Dunne et al. (1989a,b) find that 40% of firms in manufacturing in the U.S. disappear over a five year period and are replaced by new entrants.

<sup>8</sup>Because of the censoring of high-skill wages, their growth of 14.0% reflects the increase in the social security contribution ceiling rather than the real increase in wages paid to high-skilled workers.

and 1995 despite significant changes in relative factor inputs while in non-tradable industries the wages of low-skilled workers grew the most with 22.9% compared to 16.4% for medium-skilled workers and only 9.8% for high-skilled workers.

### 3 Wage and Employment Responses

Before we show how industries and firms have absorbed changes in local labour supply, we first investigate how these changes have affected skill-specific wages and employment rates in West Germany's 204 labour market regions. To do this, we estimate the following models:

$$\% \Delta w_{ir} \text{ or } \Delta \left( \frac{N_{ir}}{P_{ir}} \right) = \eta_i + \delta_r + \gamma \% \Delta L_{ir} + \varepsilon_{ir}, \quad (1)$$

where  $\% \Delta w_{ir}$  is the percentage change in gross daily wages,  $\Delta(N_{ir}/P_{ir})$  the change in the employment/labour force rate, and  $\% \Delta L_{ir}$  the percentage growth in the labour supply of education group  $i$  in region  $r$ .  $\eta_i$  and  $\delta_r$  are full sets of education and region fixed effects.

We start off by estimating both models by OLS. A well known problem in these estimations is that unobserved skill-specific local labour demand shocks may attract workers of that skill group into a particular region while at the same time increasing that group's wages and employment rates. In that case the OLS results of the parameter  $\gamma$  would be upward biased. To address this endogeneity problem we follow an approach similar to Card's (2001) and use the supply-push component of foreign immigration as an instrument for the relative factor supply changes in a locality.

The supply-push component of immigrant inflows refers to the exogenous part of the actual inflow to a local labour market that is attributable to existing ethnic concentrations. The underlying idea is that immigrants tend to settle in those areas where other immigrants of the same country of origin or cultural background have already settled before (Bartel,

1989). Suppose  $\Delta I_c$  is the net overall number of immigrants with nationality  $c$  entering Germany during a given period.<sup>9</sup> In the absence of any local labour demand shocks, these new immigrants are likely to distribute themselves across Germany according to the existing distribution of their fellow countrymen. Let  $\lambda_{cr}$  represent the share of all immigrants of nationality  $c$  in Germany that reside in labour market  $r$  at the beginning of the period and let  $\theta_{ci}$  be the nationwide fraction of the newly arriving immigrants of nationality  $c$  that fall into skill group  $i$ . Then the number of new immigrants of nationality  $c$  with skill  $i$  that is expected to move to labour market region  $r$  is given by  $\lambda_{cr} \times \theta_{ci} \times \Delta I_c$ . Summing across source countries then gives an estimate of the expected overall skill-specific immigrant inflow into local labour market  $r$ :

$$SP_{ir} = \sum_c \lambda_{cr} \theta_{ci} \Delta I_c.$$

This supply-push component of recent immigration will be exogenous as long as  $\lambda_{cr}$  is uncorrelated with local demand shocks. Since older immigrant cohorts already living in Germany are also likely to relocate to labour market  $r$  in the presence of positive economic shocks, contemporary  $\lambda_{cr}$  will violate this condition. For that reason we use past immigrant distributions, using a lag of five years. So for the period 1985 to 1995 we use the existing distributions in 1980. Finally, since we instrument the percentage change in the skill-specific labour force  $\% \Delta L_{ir}$ , we divide  $SP_{ir}$  by the overall skill-specific labour force in region  $r$  at the beginning of the immigration period. The supply-push rate we use as our instrument is then given by:

$$SPR_{ir} = \frac{\sum_c \lambda_{cr} \theta_{ci} \Delta I_c}{L_{ir_0}}. \quad (2)$$

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<sup>9</sup>In the IAB data we only observe an individual's nationality not the country of birth. This means that some foreign nationals we observe in the data are actually born in Germany but have kept their parents' nationality. According to figures from the German Statistical Office, the share of second generation immigrants in the immigrant working-age population in 1995 is around 10%.

Table 2: Summary statistics of immigrant inflow, 1985 to 1995

<b>1985-1995</b>	Immigrant inflow	% share of inflow	Low education	Intermediate education	High education
Former Yugoslavia	765,974	26.1	47.6	44.8	7.6
Asia	467,736	15.9	58.4	25.0	16.6
Poland	377,723	12.9	24.8	60.5	14.8
Turkey	321,242	11.0	78.4	16.8	4.9
Former Soviet Union	243,767	8.3	31.0	38.0	31.1
Western Europe	162,030	5.5	27.0	42.4	30.6
Africa	152,250	5.2	69.4	22.0	8.7
Romania	147,020	5.0	41.3	41.1	17.5
Central & Eastern Europe	107,677	3.7	35.3	47.7	17.0
Greece	68,505	2.3	68.2	27.9	3.8
Portugal	51,175	1.7	73.3	22.1	4.5
Italy	36,941	1.3	65.3	24.6	10.1
Central & South America	36,778	1.3	34.8	32.3	32.9
North America	7,712	0.3	32.5	15.1	52.4
Others	-13,045	-0.4	39.5	27.7	32.8
<b>All</b>	<b>2,933,485</b>	<b>100.0</b>	<b>48.6</b>	<b>37.4</b>	<b>14.0</b>

Source: Statistical Office and German Microcensus

In contrast to previous studies that have used the overall lagged foreign immigrant concentration as an instrument for current changes (for instance, Altonji and Card, 1991; Dustmann et al., 2005), this approach is more elaborate in that we distinguish between fifteen nationality-specific immigrant distributions in Germany. This is particularly important when analysing a period during which the country of origin composition of immigrant inflows has changed significantly relative to the existing immigrant stock. For a new immigrant from Asia or Yugoslavia, the two largest groups of recent immigrants to Germany, the existence of a large, say Turkish community, the largest existing immigrant group in Germany, is presumably irrelevant for his or her location decision.

Table 2 provides an overview of the size and composition of the net immigrant inflow to Germany between 1985 and 1995. Overall, nearly 3 million new immigrants arrived in Germany during that period, which corresponds to an inflow rate of 4.8%. Of these immigrants, more than a quarter originated from the territory of Former Yugoslavia as a result of the civil wars in the first half of the 1990s. The next biggest groups of immigrants came

Table 3: Impact of changes in local labour supply

1985-1995	Median wages						Employment/LF	
	all		tradable		non-tradable		all	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<b>Education groups 1 - 3</b>								
$\hat{\gamma}$	-0.03 (.03)	-0.13* (.08)	-0.04 (.03)	-0.10 (.08)	-0.14* (.07)	-0.48*** (.21)	0.01 (.02)	0.04 (.06)
1 <sup>st</sup> stage t-stat		5.9		4.8		5.9		7.2
$R^2$	0.64	0.62	0.71	0.69	0.59	0.55	0.60	0.60
Observations	540	540	476	476	602	602	612	612
<b>Education groups 1 &amp; 2</b>								
$\hat{\gamma}$	-0.09 (.07)	-0.12 (.09)	-0.01 (.05)	-0.05 (.14)	-0.59*** (.13)	-0.63*** (.19)	0.03 (.04)	0.04 (.04)
1 <sup>st</sup> stage t-stat		13.2		5.9		14.3		13.2
$R^2$	0.62	0.62	0.74	0.74	0.64	0.64	0.83	0.83
Observations	408	408	408	408	408	408	408	408

Notes: All regressions include a full set of skill and region fixed effects. For the wage regressions with all education groups, some observations drop out due to right censoring. Robust standard errors are reported in parentheses. Regressions are weighted by  $(1/N_r^{85} + 1/N_r^{95})^{-1/2}$  where  $N_r^t$  represents the overall labour force in region r in year t. A (\*) denotes statistical significance at the 10% level, a (\*\*) at the 5% level and a (\*\*\*) at the 1% level.

from Asia (15.9%), Poland (12.9%) and Turkey (11.0%). Overall, the newly arriving immigrants were relatively low-skilled compared to the existing population in Germany in 1985: 48.6% with low educational attainment (compared with 33.5% in the existing population), 37.4% with intermediate educational attainment (61.7%), and 14% with high educational attainment (4.8%), although there is substantial variation across countries of origin.

Table 3 now shows estimates of the parameter  $\gamma$  in our two regression models in Equation 1. The OLS results for the percentage change in daily wages for all workers, those in tradable industries and those in non-tradable industries are shown in columns 1, 3 and 5, respectively. Columns 2, 4 and 6 show the corresponding IV results where we use the

supply-push component of recent immigration as an instrument for the percentage change in skill-specific local labour supply. The first stage regression is strong in all estimations with t-statistics for the instrument between 4.8 and 14.3. The OLS results for all workers in column 1 show that changes in local labour supply have little impact on relative wages. The wage elasticity is estimated at -0.03. The IV result for the wage regression of -0.13 is more negative than the OLS result and statistically significant at the 10% level, pointing towards demand-driven labour flows. There are large differences in the wage response between tradable and non-tradable industries. While in tradable industries relative wages change relatively little in response to local labour supply shifts with an insignificant IV estimate of -0.10, wages in non-tradable industries are far more responsive with a wage elasticity of -0.48. As the results in columns 7 and 8 show, there is no evidence of a significant effect of labour supply changes on the employment/labour force rate in a region. In the bottom panel of Table 3 we repeat the same estimation but restrict our sample to the low and medium skill groups in each region. The parameter estimates are similar in magnitude to the case with all three education groups with somewhat larger estimates for wages in non-tradable industries. Overall, the results in Table 3 show that changes in local labour supply have relatively little impact on relative wages and employment in West Germany. All wage adjustments take place in non-tradable industries whereas wages in tradable industries remain unaffected by local labour supply conditions.<sup>10</sup> Employers in these industries seem to substitute different education groups elastically in their production process. In fact, the estimates from the OLS and IV regressions in columns 1 and 2 of the upper panel would imply an elasticity of substitution between skill groups of 33 and 8, respectively, which is significantly higher than estimates found in the related literature. For instance, Fitzenberger and Kohn (2006) estimate an elasticity of substitution of between 4.9 and 6.9 while Fitzenberger and Franz (2001) estimate an elasticity

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<sup>10</sup>The observation that relative wages respond to changes in local labour supply in non-tradable industries but not in tradable industries is somewhat puzzling under the assumption of free labour mobility across these sectors. In principle, a decline in relative wages in non-tradable industries should, in a competitive market, induce workers to move into better paying tradable industries until the wage rates in the two sectors are equalised.

between medium- and low-skilled workers of 0.6-1.4 for manufacturing and 3.0-3.6 for non-manufacturing industries in Germany. For the U.S. the typical estimate ranges between 1.5 and 2.5 (see, for instance, Bound and Johnson, 1992; Card and Lemieux, 2001; Ciccone and Peri, 2007; Katz and Murphy, 1992; Krusell et al., 2000). The question thus arises how these changes in local factor supplies are absorbed, in particular in tradable industries, without going through the mechanism of factor price adjustments.

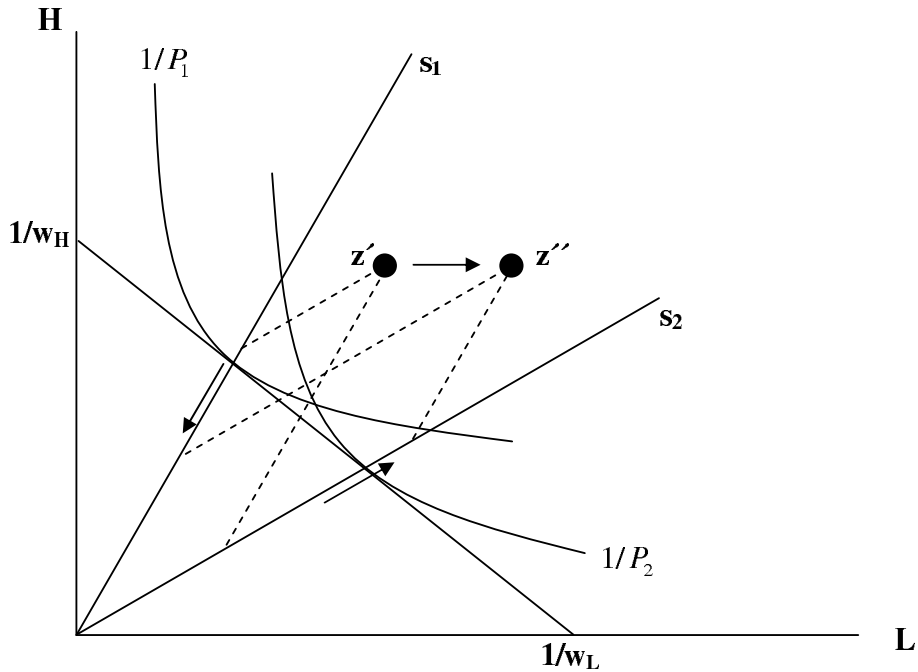
## 4 Analytical Framework

### 4.1 Industry Decomposition

In the following, we explain and graphically illustrate how changes in factor endowments in an economy can be absorbed by between and within industry changes and how these changes at the industry level can themselves be decomposed into changes between and within firms (see also Leamer, 1995, and Gaston and Nelson, 2000). We show that only at the level of the firm are we able to accurately distinguish scale and technology adjustments.

Suppose we have an economy in which there are two industries which each produce a particular tradable output good whose price is fixed on the world market with a constant returns to scale production technology using only two inputs, low-skilled workers and high-skilled workers. Let the initial endowment of the economy with both types of workers be denoted by  $z'$ . Figure 1 shows this initial situation where the number of low-skilled workers  $L$  is shown on the x-axis and the number of high-skilled workers  $H$  is shown on the y-axis. With the available technology, each industry can produce a given amount of its output good with a variety of combinations of the two labour inputs  $L$  and  $H$ . Normalising the value of each output good to 1, these combinations are depicted by the unit-value isoquants  $1/P_1$  for industry 1 and  $1/P_2$  for industry 2. Now, given there is perfect competition

Figure 1: Between industry adjustments



in all markets and labour is mobile across industries, wages have to be identical in both industries in equilibrium. Assuming full employment and cost minimisation by firms, the relative wage rate will then be uniquely determined by the slope of the isocost curve that is tangent to both unit isoquants. Denote this initial relative wage rate as  $w_L/w_H$ . The rays  $s_1$  and  $s_2$  from the origin through the tangency points of the isocost function and the unit isoquants then represent the equilibrium input ratio in each industry. The cone defined by  $s_1$  and  $s_2$  represents the so-called *cone of diversification*. Any combination of factor endowments that lies within this cone will result in both output goods being produced. In our case, both industries are active with industry 1 using high-skilled workers more intensively than industry 2. With full employment, the scale of each industry is determined by the intersection of the production rays  $s_1$  and  $s_2$  and the dashed lines through the initial factor endowment  $z'$ .

Suppose immigration increases the supply of low-skilled workers in the economy, thus shifting  $z'$  to  $z''$ . If output good prices are fixed and the technologies available remain un-

changed, then the unit-value isoquants cannot change. Therefore, relative wages cannot change either in response to the change in relative factor endowments, unless the economy specialises its production.<sup>11</sup> This is what Leamer and Levinsohn (1995) call the Factor Price Insensitivity Theorem. In order to absorb the additional workers all that happens is a change in the scale of each industry with industry 1, the skill-intensive industry, decreasing its output and industry 2 increasing it as illustrated by the arrows along the production rays  $s_1$  and  $s_2$ .<sup>12</sup> This *between industry* effect is subject of the Rybczynski Theorem (Rybczynski, 1955). The basic proposition of the Rybczynski Theorem is that with given output prices and technology, the only way an economy can react to a change in factor endowment is to change its output mix by increasing production in the industry that uses the now more abundant labour input more extensively and decreasing it elsewhere. In the context of the Heckscher-Ohlin-Samuelson model illustrated here, the only way a change in relative factor prices could be generated is through a change in the prices of output goods.

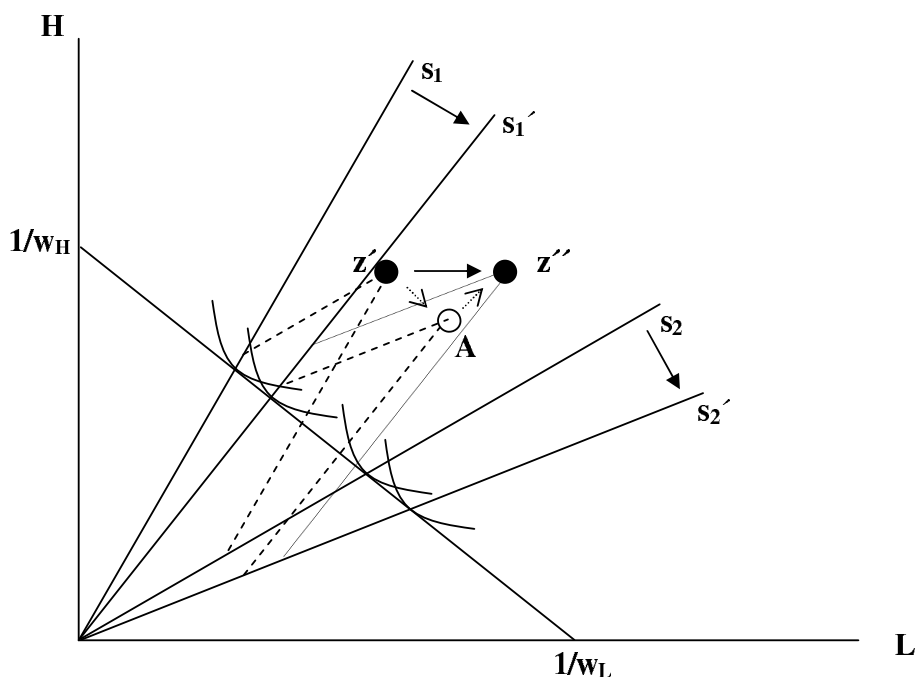
Now, we continue to assume that output prices are fixed on the international market but that industries can respond to changes in relative labour supply by changing their production technology. This situation is depicted in Figure 2. Suppose both industries change their technology towards a more low-skill intensive technology in response to the shift in labour supply. One can think of this endogenous technology change as a clockwise rotation of the cone of diversification around the origin as shown in the graph. The deviation of the new isocost curve from the initial one could in that case be small. To avoid

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<sup>11</sup>For a formal derivation of these results see, for example, Dustmann et al. (2005). In general, an economy's ability to absorb changes in relative labour supply without changing its relative wage structure depends on the number of traded goods produced relatively to the number of distinct labour inputs. Derived from trade theory models, Woodland (1982) and Ethier (1984) show the relevant algebra, also allowing for the existence of non-traded goods (see also Komiyama, 1967, and Ethier, 1972).

<sup>12</sup>It should be pointed out that this has to be considered as a long-run effect. In the short run, the increase in low-skill labour supply will lead to a decrease in relative wages. This change in relative wages in turn leads to a relatively larger decrease in unit production costs for the low-skill intensive industry than for the skill intensive industry. When output prices are fixed, there will be positive profits in the low-skill intensive industry. In a perfectly competitive market these profits then induce new firms to enter the industry (or firms to move from the skill intensive to the more profitable low-skill intensive industry), increasing relative demand for low-skilled workers and driving relative wages back to the original level.

Figure 2: Within industry adjustments



cluttering the diagram, we illustrate the case, in principle feasible, in which the isocost curve remains unchanged, so that relative wages do not respond to changes in technology. Suppose the scale of an industry is given by the distance between the origin and the intersection of the dashed line with the corresponding production ray. A suitable rotation of the cone of diversification (illustrated by the move from  $z'$  to A) and a subsequent proportional increase in scale in both industries in order to ensure full employment (illustrated by the move from A to  $z''$ ) will leave the relative scale of each industry unchanged.<sup>13</sup> Endogenous changes in production technology hence offer an alternative explanation of how industries can adjust to changes in relative labour supply. Such *within industry* technology adjustments could be identified from observing a change in relative factor inputs within industries with constant relative scales of the industries and the absence of changes in relative wages.<sup>14</sup> Of course, it is likely that both between and within industry adjustments

<sup>13</sup>Analytically, this is not accurate but helps to visualise the underlying process.

<sup>14</sup>If relative wages do change, then it is not clear whether changes in relative output prices have shifted the unit-value isoquants and the industries continue to produce with their original technology, or whether there is a set of new technologies that leads to a new relative wage equilibrium.

take place simultaneously. We will start off by quantifying which of the two has been dominant in Germany over the period 1985 to 1995.

Following Lewis (2004b), we decompose the relative growth in labour supply of skill group  $i$  in a locality into four components: a scale effect capturing growth in the size of industries  $j$  holding relative factor inputs constant, an intensity effect capturing how industries change their relative factor inputs holding overall size constant, a residual term consisting of the interaction of both these effects, and relative growth in skill-specific unemployment in the locality. This decomposition is given by

$$\begin{aligned}
\frac{\Delta L_i}{L_{i0}} &= \sum_j s_{ij0} \% \Delta M_j && \text{industry scale effect} \\
&+ \sum_j s_{ij0} \% \Delta \left( \frac{N_{ij}}{M_j} \right) && \text{industry intensity effect} \\
&+ \sum_j s_{ij0} \% \Delta M_j \cdot \% \Delta \left( \frac{N_{ij}}{M_j} \right) && \text{industry residual term} \\
&+ s_{iu0} \% \Delta U_i && \text{unemployment growth,}
\end{aligned} \tag{3}$$

where  $L_i$  is the labour supply of skill  $i$ ,  $M_j$  is the overall employment in industry  $j$ ,  $N_{ij}$  is the overall employment of skill  $i$  in industry  $j$ , and  $U_i$  is the overall number of unemployed individuals of skill  $i$  (for details see Appendix B).<sup>15</sup> The subscript 0 denotes the base year 1985. With this notation, we have

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<sup>15</sup>An alternative to overall employment as a measure of the size of an industry would be industry-specific output. That information, however, is difficult to obtain for all industries and, in particular, for the entirety of firms once we move the analysis to the firm level. Lewis (2004b) shows that for manufacturing industries in the U.S., the results for the between industry scale effect do not depend on whether the size of an industry is measured by output or total employment.

$$\begin{aligned}
& \frac{\Delta L_i}{L_{i0}}: \text{percentage change in supply of type } i \text{ workers} \\
s_{ij0} = \frac{N_{ij0}}{L_{i0}}: & \text{initial share of type } i \text{ workers employed in industry } j \\
\% \Delta M_j: & \text{percentage change in overall employment in industry } j \\
\% \Delta \left( \frac{N_{ij}}{M_j} \right): & \text{percentage change in relative intensity of type } i \text{ workers in industry } j \\
s_{iu0} = \frac{U_{i0}}{L_{i0}}: & \text{initial unemployment rate of type } i \text{ workers} \\
\% \Delta U_i: & \text{percentage change in number of unemployed type } i \text{ workers.}
\end{aligned}$$

To estimate the relative contribution of adjustments in scale, intensity, residual and unemployment in absorbing changes in local labour supply, we regress each of the four components in Equation 3 on the percentage change in labour supply in a region plus a full vector of region fixed effects  $\theta_r$ , which account for scale effects common to all industries in each region, and skill group fixed effects  $\lambda_i$ , which account for exogenous changes in the relative usage of different labour types in all industries and regions. For the scale effect, for instance, our estimation equation is then given by

$$\sum_j s_{ijr0} \% \Delta M_{jr} = y_{ir} = \lambda_i + \theta_r + \beta \% \Delta L_{ir} + \varepsilon_{ir}, \quad (4)$$

where  $r$  denotes the labour market region. We estimate these models both by OLS and IV, using the supply-push component of recent immigrant inflows (compare Section 3) as an instrument for the potentially endogenous labour supply growth in a locality. Table 4 shows the results for the parameter  $\beta$  for each of these four regressions. Each estimate represents the corresponding share of the change in local labour supply that is absorbed.<sup>16</sup>

Focussing on the estimates of the IV regressions, we see that 62% of the changes in local labour supply are absorbed within industries while only around 20% are absorbed between industries. Qualitatively, this result accords with Lewis's findings for the period

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<sup>16</sup>Since in some regions not all industries existed in the base year of the regression so that  $s_{ij0} = 0$  and in others industries ceased to exist so that  $\% \Delta M_j = 0$  and  $\% \Delta (N_{ij}/M_j) = 0$ , we add an additional component *Net New Industries* given by  $\sum_{j_{old,new}} (\Delta N_{ij}/L_{i0})$ , which captures the contribution from these few new and old industries.

Table 4: Decomposition of changes in labour supply on the industry level

1985-1995	Between Industries	Within Industries	Net New Industries	Ambiguous	Unemployment
<b>OLS</b>					
Labour Supply Growth	0.128*** (.019)	0.541*** (.027)	0.002 (.001)	0.201*** (.020)	0.128*** (.020)
<b>IV</b>					
Labour Supply Growth	0.201*** (.070)	0.620*** (.070)	0.007** (.003)	0.135** (.054)	0.039 (.049)

Notes: All regressions use 612 observations and include a full set of skill and region fixed effects. Robust standard errors are reported in parentheses. Regressions are weighted by  $(1/N_r^{85} + 1/N_r^{95})^{-1/2}$  where  $N_r^t$  represents the overall labour force in region  $r$  in year  $t$ . The first stage t-stat is 6.0. A (\*) denotes statistical significance at the 10% level, a (\*\*) at the 5% level and a (\*\*\*) at the 1% level.

1980 to 1990 in the U.S., although his estimates show a quantitatively larger adjustment within industries of 74% and a smaller adjustment of only 4% between industries.

Table 5 now further decomposes these relative contributions into those coming from industries that produce tradable goods and those coming from industries that produce non-tradable goods. In principle, industries in the tradable sector face output good prices that are fixed on the international market, ruling out output price adjustments in response to changes in factor supplies. Interestingly, for the period 1985 to 1995, the estimates show that in tradable industries the within adjustments are particularly pronounced (44.9% compared with only 17.1% in non-tradable industries) while the opposite is true for the between industry adjustments (15.2% in non-tradable industries compared with only 4.8% in tradable ones). Given that the overall scale of the tradable and non-tradable industry sectors are approximately the same in the base year 1985 (49.1% and 50.9% of overall employment, respectively), one would expect both types of industries to contribute equally to the overall between and within industry effects if they reacted in the same way to changes in local factor supplies. This result is somewhat surprising in the context of the Heckscher-Ohlin-Samuelson model if we rule out endogenous changes in technology since in the non-tradable sector there is more scope for relative wage adjustments due to more output price flexibility and thus for more adjustments in the relative use of different

Table 5: Decomposition of changes in labour supply on the industry level, by industry type

1985-1995	Between Industries		Within Industries		Net New Industries	Ambi- guous	Unem- ployment
	tradable	non-trad.	tradable	non-trad.			
<b>OLS</b>							
Labour Supply Growth	0.128*** (.019)		0.541*** (.027)		0.002 (.001)	0.201*** (.020)	0.128*** (.020)
	0.080*** (.016)	0.048*** (.010)	0.337*** (.042)	0.205*** (.025)			
<b>IV</b>							
Labour Supply Growth	0.201*** (.070)		0.620*** (.070)		0.007** (.003)	0.135** (.054)	0.039 (.049)
	0.048 (.053)	0.152*** (.035)	0.449*** (.101)	0.171** (.070)			

Notes: All regressions use 612 observations and include a full set of skill and region fixed effects. Robust standard errors are reported in parentheses. Regressions are weighted by  $(1/N_t^{85} + 1/N_t^{95})^{-1/2}$  where  $N_t^r$  represents the overall labour force in region  $r$  in year  $t$ . Overall employment in 1985 was 8,513,067 (49.1%) in firms in tradable industries and 8,828,637 (50.9%) in firms in non-tradable industries. The first stage t-stat in the IV regressions is 6.0. A (\*) denotes statistical significance at the 10% level, a (\*\*) at the 5% level and a (\*\*\*) at the 1% level.

labour inputs.

Overall, the results suggest that only a relatively small fraction of the changes in labour supply are absorbed by an expansion of those industries that use the more abundant factor more intensively as predicted by the traditional Heckscher-Ohlin-Samuelson model. The majority of adjustment happens through changes in the skill intensity within industry, particularly so in tradable industries while non-tradable industries show a relatively large adjustment in scale. Under the assumption of fixed output good prices, a possible explanation for this finding could be endogenous changes in production technologies. However, since changes in technology are implemented within firms rather than industries, it is crucial to take the analysis to the firm level. As we will see, only an analysis at that level will allow us to unambiguously attribute the large observed changes in skill intensity within industries to actual technological changes within firms.

## 4.2 Firm Contributions to Industry Effects

With firm level data available, a natural first step would be to decompose the terms capturing the scale and intensity effects on the industry level in Equation 3 and distinguish between the contributions of permanent firms  $f^p$ , new firms  $f^n$  and old firms  $f^o$ . Permanent firms are defined as firms that exist in both periods, 1985 and 1995, new firms are firms that do not exist in the base year 1985 but exist in 1995, and old firms are firms that exist in 1985 but do not exist anymore in 1995.

The scale effect on the industry level can then be written as:

$$\begin{aligned} \sum_j s_{ij_0} \cdot \% \Delta M_j &= \sum_j \sum_{f^p} s_{ij_0} \left( \frac{M_{jff^p} - M_{jff_0^p}}{M_{j_0}} \right) && \text{permanent firms scale contribution} \\ &+ \sum_j \sum_{f^n} s_{ij_0} \left( \frac{M_{jff^n}}{M_{j_0}} \right) && \text{new firms scale contribution} \\ &- \sum_j \sum_{f^o} s_{ij_0} \left( \frac{M_{jff_0^o}}{M_{j_0}} \right) && \text{old firms scale contribution,} \end{aligned} \quad (5)$$

where  $M_{jfx}$  is total employment in a firm of type  $x = (p, n, o)$ .<sup>17</sup>

The industry intensity effect of Equation 3 can be decomposed as follows:

$$\begin{aligned} \sum_j s_{ij_0} \cdot \% \Delta \left( \frac{N_{ij}}{M_j} \right) &= \sum_j \sum_{f^p} s_{ij_0} \left( \frac{\frac{N_{ijf^p}}{M_j} - \frac{N_{ijf_0^p}}{M_{j_0}}}{\frac{N_{ij_0}}{M_{j_0}}} \right) && \text{permanent firms intensity contribution} \\ &+ \sum_j \sum_{f^n} s_{ij_0} \left( \frac{\frac{N_{ijf^n}}{M_j}}{\frac{N_{ij_0}}{M_{j_0}}} \right) && \text{new firms intensity contribution} \\ &- \sum_j \sum_{f^o} s_{ij_0} \left( \frac{\frac{N_{ijf_0^o}}{M_{j_0}}}{\frac{N_{ij_0}}{M_{j_0}}} \right), && \text{old firms intensity contribution,} \end{aligned} \quad (6)$$

where  $N_{ijfx}$  is the number of type  $i$  workers employed in a firm of type  $x$ .

<sup>17</sup>Total employment in every new firm in 1985 is zero, so  $M_{jff_0^n} = 0$ , and total employment in every old firm in 1995 is zero, so  $M_{jff_0^o} = 0$ , which gives the second and third term.

Table 6: Decomposition of changes in labour supply - from industry to firm level, by industry type

1985-1995	Between Industries				Within Industries			
	Permanent		Net New		Permanent		Net New	
Level	tradable	non-trad.	tradable	non-trad.	tradable	non-trad.	tradable	non-trad.
<b>OLS</b>								
Industry		0.128*** (.019)				0.541*** (.027)		
Firm	0.091*** (.014)		0.038*** (.013)		0.436*** (.034)		0.106*** (.025)	
Firm/ tradability	0.061*** (.013)	0.029*** (.006)	0.020* (.011)	0.019** (.009)	0.292*** (.044)	0.144*** (.021)	0.045* (.024)	0.061*** (.010)
<b>IV</b>								
Industry		0.201*** (.070)				0.620*** (.070)		
Firm	0.095** (.043)		0.108*** (.042)		0.471*** (.075)		0.152*** (.047)	
Firm/ tradability	0.042 (.028)	0.052* (.027)	0.008 (.036)	0.101*** (.022)	0.372*** (.101)	0.099 (.060)	0.079* (.046)	0.073** (.032)

Notes: All regressions use 612 observations and include a full set of skill and region fixed effects. Robust standard errors are reported in parentheses. Regressions are weighted by  $(1/N_r^{85} + 1/N_r^{95})^{-1/2}$  where  $N_r^t$  represents the overall labour force in region  $r$  in year  $t$ . Overall employment in 1985 was 8,513,067 (49.1%) in firms in tradable industries and 8,828,637 (50.9%) in firms in non-tradable industries. The first stage t-stat in the IV regressions is 6.0. A (\*) denotes statistical significance at the 10% level, a (\*\*) at the 5% level and a (\*\*\*) at the 1% level.

These are simple decompositions which allow us to assess the contributions made by permanent, new and old firms to the overall scale and intensity effects found on the industry level. For clarity we summarise the joint effect of new and old firms in a category called *Net New Firms*. Table 6 reports the results for each of the four components, two for the scale effect and two for the intensity effect, together with the original estimates from the industry level estimations as reported in Table 4.

Focussing on the second row for the IV estimations, we can see that of the 20.1% of changes in labour supply that are absorbed by between industry adjustments, 9.5 percentage points are absorbed by permanent firms and 10.8 by the net creation of new firms. By contrast, of the within industry component of 62%, 47.1 percentage points are absorbed by permanent firms and 15.2 percentage points by new firms.

Table 7: Decomposition of changes in labour supply - from industry to firm level, by firm size

1985-1995	Between Industries				Within Industries			
	Permanent		Net New		Permanent		Net New	
Level	small	large	small	large	small	large	small	large
<b>OLS</b>								
Industry		0.128*** (.019)				0.541*** (.027)		
Firm	0.091*** (.014)		0.038*** (.013)		0.436*** (.034)		0.106*** (.025)	
Firm/ size	0.023*** (.007)	0.067*** (.014)	0.049*** (.008)	-0.011 (.009)	0.192*** (.018)	0.244*** (.042)	0.110*** (.012)	-0.004 (.022)
<b>IV</b>								
Industry		0.201*** (.070)				0.620*** (.070)		
Firm	0.095** (.043)		0.108*** (.042)		0.471*** (.075)		0.152*** (.047)	
Firm/ size	-0.004 (.018)	0.099*** (.034)	0.081*** (.018)	0.027 (.032)	0.474*** (.054)	-0.003 (.087)	0.235*** (.030)	-0.084** (.041)

Notes: All regressions use 612 observations and include a full set of skill and region fixed effects. Robust standard errors are reported in parentheses. Regressions are weighted by  $(1/N_r^{85} + 1/N_r^{95})^{-1/2}$  where  $N_r^t$  represents the overall labour force in region  $r$  in year  $t$ . Overall employment in 1985 was 8,482,928 (48.9%) in small firms and 8,858,776 (51.1%) in large firms. The first stage t-stat in the IV regressions is 6.0. A (\*) denotes statistical significance at the 10% level, a (\*\*) at the 5% level and a (\*\*\*) at the 1% level.

Decomposing these contributions further, the last row in Table 6 shows the relative contributions of firms operating in the tradable and non-tradable sector. Given that the two types of sectors are of roughly the same size in the base year 1985 and the share of permanent firms is similar (compare Table 1), it is particularly interesting to see that the majority of within industry adjustments contributed by permanent firms comes from firms in the tradable sector with 37.2% compared to only 9.9% for non-tradable firms.

Table 7 has the same structure as Table 6 but this time distinguishes contributions by small and large firms. A firm is defined as large if it has more than 100 full-time employees in 1985 or, for a new firm, if it has more than 100 full-time employees in 1995. Focussing again on the IV results in the bottom row, we can see that large firms contribute substantially to the between industry adjustment component with 9.9% compared to only -0.4% for small firms, while small firms contribute disproportionately to the within industry component with 47.4% compared to only -0.3% for large firms.

### 4.3 A New Firm Level Decomposition

Despite offering a good insight into the relative contributions of permanent, new and old firms to the measured between and within industry effects, the decompositions in Equations 5 and 6 cannot directly be interpreted as scale and intensity effects on the firm level.

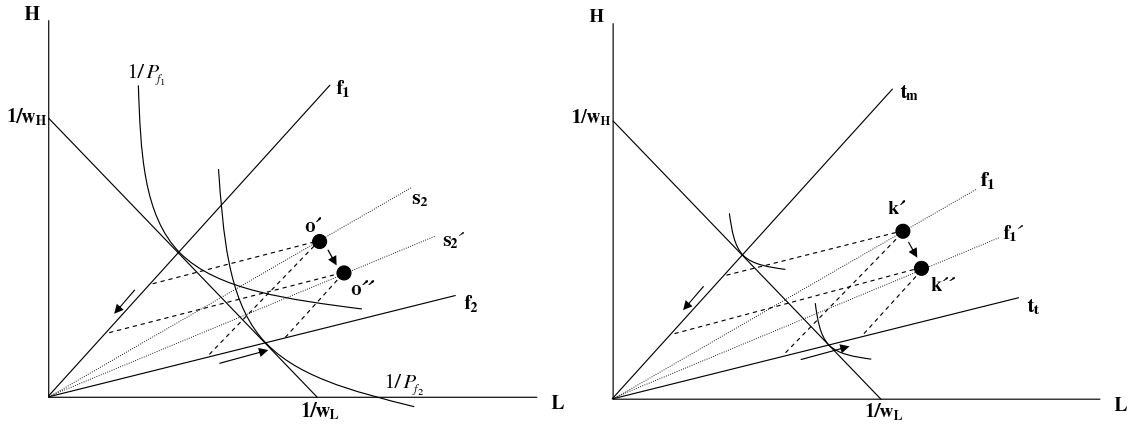
To see this, assume that all the adjustments happen within industries as suggested by the findings of Lewis (2004b). Focussing on industry 2 for the moment, the left graph in Figure 3 depicts this change in technology by the move from the optimal labour input ratio  $s_2$  to the new optimal ratio  $s_2'$ . Now suppose this industry consists of two firms, firm 1 and firm 2, and that both these firms produce a different output good with technologies  $f_1$  and  $f_2$ , where firm 1 is using a skill-intensive technology relative to firm 2. The unit-value isoquants for firm 1 and firm 2 are given by  $1/P_{f_1}$  and  $1/P_{f_2}$ , where  $P_{f_1}$  and  $P_{f_2}$  are the prices of the output goods produced by firm 1 and firm 2. Similar to the line of argument that explains the between industry adjustment mechanism, when output prices are fixed, the observed within industry intensity effect could be fully explained by a *within industry between firm* scale effect, which we simply call the *between firm* effect, with the skill-intensive firm 1 decreasing its output and the low-skill intensive firm 2 increasing it as illustrated by the arrows along the production rays  $f_1$  and  $f_2$ .<sup>18</sup> This suggests that there are potential pitfalls from aggregating to the industry level and that one potentially misinterprets evidence of changes in relative factor inputs within industries as endogenous technology adjustments.

Such endogenous technology adjustments could in turn be represented by a clockwise rotation of the within industry cone of diversification similar to the way described in Section 4.1. Suppose in every firm there exist two competing modes of technology (or organisation), a traditional  $t_t$  and a modern one  $t_m$ , that are simultaneously in use as suggested

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<sup>18</sup>Presumably, labour mobility between firms of the same industry is easier than between industries so that the assumption of constant relative wages across firms within the same industry is more likely to hold than across industries.

Figure 3: Between and within firm adjustments



by Beaudry and Green (2003, 2005).<sup>19</sup> This situation is depicted for firm 1 in the right graph of Figure 3. A possible explanation of how a firm endogenously adjusts to changes in relative factor supplies without changing its relative wage structure is by changing its relative usage of the two technologies. In the example of low-skilled immigration, the firm increases its use of the low-skill intensive technology while decreasing the use of the high-skill intensive technology as illustrated by the arrows along the technology-specific production rays  $t_t$  and  $t_m$ . As a consequence of this technology adjustment, the equilibrium factor input ratio of firm 1 will change as depicted by the shift from  $f_1$  to  $f_1'$ . We call this effect the *within industry within firm* intensity effect, or simply the *within firm* effect.

We now show under which conditions industry and firm level analyses lead to the same conclusions with regard to the relative magnitude of between and within effects and quantify the actual discrepancies resulting from the aggregation to the industry level.

In order to identify between and within firm effects, a useful decomposition would be to

<sup>19</sup>In their model of endogenous technological adoption, Beaudry and Green (2003, 2005) emphasise the importance of physical capital in determining changes in the wage-education relationship. Unfortunately, there is no data available on the stock of physical capital employed in the firms in our data, so that we cannot investigate the role capital movements play in firms' adjustment processes in response to local labour supply changes.

start off by writing the change in the labour supply of skill group  $i$  in a locality as the sum of changes in employment of workers with skill level  $i$  in each industry  $j$  and the change in the number of unemployed workers with skill level  $i$ :

$$\Delta L_i = \sum_j \Delta N_{ij} + \Delta U_i.$$

In each industry  $j$  there are now a number of firms operating. Let us divide these firms as before into three groups:

- $f^p$ : *permanent* firms that appear in both periods
- $f^n$ : *new* firms that were established between 1985 and 1995
- $f^o$ : *old* firms that went out of business between 1985 and 1995

The percentage change in labour supply can then be decomposed in the following way (for details see Appendix C):

$$\frac{\Delta L_i}{L_{i0}} = \sum_j \sum_{f^p} s_{ij0} s_{ijf_0^p} (\% \Delta N_{ijf^p}) + \sum_j \sum_{f^n} \frac{\Delta N_{ijf^n}}{L_{i0}} - \sum_j \sum_{f^o} s_{ij0} s_{ijf_0^o} + s_{iu0} \% \Delta U_i, \quad (7)$$

where  $N_{ijf}$  is the overall employment of skill  $i$  in firm  $f$  that operates in industry  $j$ , so that

$$\begin{aligned}
s_{ij_0} &= \frac{N_{ij_0}}{L_{i_0}}: && \text{initial share of type } i \text{ workers employed in industry } j \\
s_{ijf_0^x} &= \frac{N_{ijf_0^x}}{N_{ij_0}}: && \text{initial share of type } i \text{ workers in industry } j \text{ employed in firm } f^x \\
\% \Delta N_{ijf^p} &: && \text{percentage change in number of type } i \text{ workers employed in } \textit{permanent} \text{ firm } f^p \\
\frac{\% \Delta N_{ijf^n}}{L_{i_0}} &: && \text{percentage change in number of type } i \text{ workers employed in } \textit{new} \text{ firm } f^n \text{ relative to initial labour force of type } i \\
s_{iu_0} &= \frac{U_{i_0}}{L_{i_0}}: && \text{initial unemployment rate of type } i \text{ workers} \\
\% \Delta U_i &: && \text{percentage change in number of unemployed type } i \text{ workers}
\end{aligned}$$

Now let  $M_{jf}$  be a measure of the size of a firm  $f$  in industry  $j$ , in our case total employment. Then we can decompose the firm-specific percentage change in employment of type  $i$  workers for all permanent firms (and only for these firms) into three terms (again, for details see Appendix C):

$$\% \Delta N_{ijf} = \% \Delta M_{jfp} + \% \Delta \left( \frac{N_{ijfp}}{M_{jfp}} \right) + \% \Delta M_{jfp} \cdot \% \Delta \left( \frac{N_{ijfp}}{M_{jfp}} \right), \quad (8)$$

where

$$\begin{aligned}
\% \Delta M_{jfp} &: && \text{percentage change in total employment of firm } f^p \text{ in industry } j \\
\% \Delta \left( \frac{N_{ijfp}}{M_{jfp}} \right) &: && \text{percentage change in type } i \text{ labour intensity in firm } f^p \text{ in industry } j.
\end{aligned}$$

The first term thus represents a firm-specific scale effect while the second term represents changes in the firm-specific relative factor intensity. The interaction of both effects is captured in the third term. Substituting Equation 8 into Equation 7, we then obtain an expression that decomposes the change in skill-specific labour supply into six distinct components.<sup>20</sup>

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<sup>20</sup>There are some regions where the number of unemployed workers with college education in the sample in the initial period is zero so that it is not possible to obtain the growth rate  $\% \Delta U_i$ . In these few cases we calculate  $\Delta U_i / L_{i_0}$  rather than  $s_{iu_0} \% \Delta U_i$  which is, of course, equivalent.

Table 8: Decomposition of changes in labour supply on the firm level

1985-1995	Permanent scale	Permanent intensity	Net New firms	Ambiguous	Unemployment
<b>OLS</b>					
Labour Supply Growth	0.191*** (.036)	0.293*** (.050)	0.217*** (.026)	0.171*** (.044)	0.128*** (.020)
<b>IV</b>					
Labour Supply Growth	0.134** (.068)	0.311** (.128)	0.232*** (.044)	0.285** (.120)	0.039 (.049)

Notes: All regressions use 612 observations and include a full set of skill and region fixed effects. Robust standard errors are reported in parentheses. Regressions are weighted by  $(1/N_r^{85} + 1/N_r^{95})^{-1/2}$  where  $N_r^t$  represents the overall labour force in region  $r$  in year  $t$ . First stage t-stat is 6.0. A (\*) denotes statistical significance at the 10% level, a (\*\*) at the 5% level and a (\*\*\*) at the 1% level.

$$\begin{aligned}
\frac{\Delta L_i}{L_{i0}} = & \sum_j \sum_{f^p} s_{ij0} s_{ijf_0^p} \cdot \% \Delta M_{jfp} && \text{permanent firms scale effect} \\
& + \sum_j \sum_{f^p} s_{ij0} s_{ijf_0^p} \cdot \% \Delta \left( \frac{N_{ijfp}}{M_{jfp}} \right) && \text{permanent firms intensity effect} \\
& + \sum_j \sum_{f^p} s_{ij0} s_{ijf_0^p} \cdot \% \Delta M_{jfp} \cdot \% \Delta \left( \frac{N_{ijfp}}{M_{jfp}} \right) && \text{residual term permanent firms} \\
& + \sum_j \sum_{f^n} \frac{\Delta N_{ijfn}}{L_{i0}} && \text{new firms contribution} \\
& - \sum_j \sum_{f^o} s_{ij0} s_{ijf_0^o} && \text{old firms contribution} \\
& + s_{iu0} \% \Delta U_i && \text{unemployment growth.}
\end{aligned} \tag{9}$$

We regress each of these components on the percentage change in skill-specific labour supply in a region. The model is the same as in Section 4.1:

$$y_{ir} = \lambda_i + \theta_r + \beta \% \Delta L_{ir} + \varepsilon_{ir}$$

where  $y_{ir}$  is one of our outcome variables, and  $\lambda_i$  and  $\theta_r$  are education group and region fixed effects respectively. Table 8 reports the corresponding results. As before, we estimate both by OLS and IV, using the predicted immigrant inflow to instrument the potentially endogenous labour supply growth in a locality. Focussing on the IV results for

the period 1985 to 1995, we can see that 13.4% of the change in labour supply is absorbed by an increase in scale of permanent firms while 31.1% is absorbed by changes in relative factor intensities. This contribution is what could be considered as arising from endogenous changes in production technology as suggested by Lewis's work. However, the corresponding estimate on the industry level in Table 4 gave a share of 62.0%. An analysis on the industry level thus clearly misrepresents the importance of technology adjustments in absorbing changes in local labour supply. The main difference between the results on the industry and firm level arises from the (net) creation of firms which contributes a significant 23.2%. Interestingly, even compared to the *within* results that we obtained after breaking down the industry effects into the contributions by permanent and net new firms (compare Table 6) our estimates in Table 8 show a smaller *within* effect, 31.1% vs 47.1%, and a larger *between* effect, 13.4% vs 9.5% in permanent firms. The reason for these discrepancies is that in the former decomposition, we are not holding each individual firm's relative factor inputs and scales constant as necessary to accurately distinguish between and within effects.

In particular, the contribution to the industry scale effect coming from permanent firms in Equation 5 equals the firm scale effect given in Equation 9 plus a residual term:<sup>21</sup>

$$\underbrace{\sum_j \sum_{f^p} s_{ij_0} \left( \frac{M_{jff^p} - M_{jff_0^p}}{M_{j_0}} \right)}_{\substack{\text{permanent firm contribution} \\ \text{industry scale effect}}} = \underbrace{\sum_j \sum_{f^p} s_{ij_0} s_{ijf_0^p} \cdot \% \Delta M_{jff^p}}_{\substack{\text{permanent firm} \\ \text{scale effect}}} - \underbrace{\sum_j \sum_{f^p} s_{ij_0} \left( \frac{N_{ijf_0^p}}{N_{ij_0}} - \frac{M_{jff_0^p}}{M_{j_0}} \right) \left( \frac{M_{jff^p} - M_{jff_0^p}}{M_{jff_0^p}} \right)}_{\text{residual term}}$$

As long as the second term is different from zero, the two scale effects will not be identical. If all firms in the same industry  $j$  produce with the same relative factor inputs in the base year, then  $\left( \frac{N_{ijf_0^p}}{N_{ij_0}} - \frac{M_{jff_0^p}}{M_{j_0}} \right) = 0$ , and the industry based scale effect of permanent firms

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<sup>21</sup>See Appendix D for details as well as the remaining decompositions of the terms for new and old firms, and an overview.

will be identical to the firm based scale effect.

Similarly, the contribution to the industry intensity effect coming from permanent firms in Equation 6 equals the firm intensity effect in Equation 9 plus a residual term:

$$\underbrace{\sum_j \sum_{f^p} s_{ij_0} \left( \frac{N_{ijf^p}}{M_j} - \frac{N_{ijf_0^p}}{M_{j_0}} \right)}_{\text{permanent firm contribution industry intensity effect}} = \underbrace{\sum_j \sum_{f^p} s_{ij_0} s_{ijf_0^p} \cdot \% \Delta \left( \frac{N_{ijf^p}}{M_{j^p}} \right)}_{\text{permanent firm intensity effect}} + \underbrace{\sum_j \sum_{f^p} s_{ij_0} s_{ijf_0^p} \left( \frac{N_{ijf^p}}{M_{j^p}} \cdot \frac{(M_{j^p} - M_j)}{M_{j_0}} \right)}_{\text{residual term}}$$

As before, as long as the second term is different from zero, the two intensity effects will not be identical. If all firms in the same industry  $j$  grow at the same rate (so there is no “between” effect within industry), then the second term of the right hand side of the last equation will be zero for all firms since  $(\frac{M_{j^p}}{M_{j_0^p}} - \frac{M_j}{M_{j_0}}) = 0$  and the industry based intensity effect of permanent firms will be identical to the firm based intensity effect. The two residual terms thus capture the “aggregation bias” that results from aggregating firms to industries.

Comparing the results for permanent firms from the industry analysis in Table 6 and those on the firm level in Table 8, we see that the relative magnitude of the residual terms arising from the aggregation to the industry level is substantial. In our case, they amount to minus 29% of the true firm scale effect  $(\frac{0.095-0.134}{0.134})$ , and 51% of the true firm intensity effect  $(\frac{0.471-0.311}{0.311})$ . These discrepancies reflect a typical aggregation problem. Given the large degree of heterogeneity of firms and their products within industries (see, for instance, Bernard and Jensen, 2002), such an aggregation is potentially very problematic, especially in the context of technology adjustments, which, in the end, take place on the firm level.

Given the importance of the net creation of new firms in absorbing changes in local labour supply, it is of particular interest to try to characterise its contribution as either a scale or

an intensity contribution. Because these firms did not exist in the base year or have ceased to operate since, one cannot use the firm-specific growth rates in scale and skill-specific factor intensities as we have for permanent firms. However, a natural benchmark for the production technology of new and old firms in an industry is the average production technology (in terms of relative factor inputs) in that industry in the base year. Specifically, one can re-write the contribution of both new and old firms given in Equation 9 as the sum of two terms

$$\begin{aligned}
 \underbrace{\sum_j \sum_{f^n} \frac{N_{ijf^n}}{L_{i0}}}_{\text{new firms contribution}} &= \underbrace{\sum_j \sum_{f^n} s_{ij0} \left( \frac{M_{jfn}}{M_{j0}} \right)}_{\text{new firms scale effect}} + \underbrace{\sum_j \sum_{f^n} s_{ij0} \left( \frac{M_{jfn}}{M_{j0}} \right) \left( \frac{N_{ijf^n}}{M_{jfn}} - \frac{N_{ij0}}{M_{j0}} \right)}_{\text{new firms intensity effect}}, \\
 -\underbrace{\sum_j \sum_{f^o} \frac{N_{ijf^o}}{L_{i0}}}_{\text{old firms contribution}} &= -\underbrace{\sum_j \sum_{f^o} s_{ij0} \left( \frac{M_{jf^o}}{M_{j0}} \right)}_{\text{old firms scale effect}} - \underbrace{\sum_j \sum_{f^o} s_{ij0} \left( \frac{M_{jf^o}}{M_{j0}} \right) \left( \frac{N_{ijf^o}}{M_{jf^o}} - \frac{N_{ij0}}{M_{j0}} \right)}_{\text{old firms intensity effect}},
 \end{aligned}$$

where the fraction  $N_{ij0}/M_{j0}$  in the second term on the right hand side of each equation is the average factor share of skill type  $i$  in industry  $j$  in the base year 1985. While the first term in each equation can be interpreted as the contribution of new and old firms to the scale of the industry, the second term captures the factor intensity contribution that goes beyond the average industry-wide factor intensity in the base year. If a new firm produces with exactly the same factor intensity as the industry average used to, then  $(\frac{N_{ijf^n}}{M_{jfn}} - \frac{N_{ij0}}{M_{j0}}) = 0$  and the second term in the first equation is zero so that the creation of this new firm can be exclusively interpreted as a contribution to the scale effect. Similarly, if an old firm produced with exactly the same factor intensity as the industry average in 1985, then  $(\frac{N_{ijf^o}}{M_{jf^o}} - \frac{N_{ij0}}{M_{j0}}) = 0$  and its destruction can again be interpreted as solely a contribution to the scale effect. Note that each leading term on the right hand side of the previous equations is identical to the contribution of new and old firms, respectively, to the industry scale effect in Equation 5. With an IV estimate of 0.108 for the net contribution of these terms (compare Table 6) and an IV estimate of the overall net new firms

contribution of 0.232 (compare Table 8), the overall intensity contribution of new and old firms is given by  $0.232 - 0.108 = 0.124$ . So roughly half of what the net creation of new firms contributes to the absorption of local labour supply changes can be considered as a scale effect and about half as an intensity adjustment. Overall, the analysis on the firm level thus reveals that 43.5% of changes in local labour supply are absorbed by changes in relative factor intensities (31.1% by permanent and 12.4% by new firms) and 24.2% by a differential growth in the scale of firms (13.4% by permanent and 10.8% by new firms). Compared to the corresponding intensity and scale contributions estimated on the industry level of 62.0% and 20.1% respectively (compare Table 4), these figures imply that the contribution of changes in production technology may have been overestimated on the industry level relative to the contribution of changes in scale but that intensity adjustments are nonetheless the more important channel through which local firms adjust to changes in relative factor supplies.

Table 9 shows the firm contributions if we distinguish between firms in tradable industries and those in non-tradable industries. The IV results show that the bulk of the overall scale effect of 13.4% comes from firms in non-tradable industries (10.5%), while pretty much all of the intensity effect arises from firms in tradable industries (34.6%). About two thirds of the contribution from new firms comes from new firms in non-tradable industries and one third from firms in tradable industries. This difference reflects the differential growth in overall employment of the non-tradable and tradable sector with the former growing by 7.5% and the latter shrinking by 4.2% between 1985 and 1995.

With regard to the size of the firms, Table 10 shows that most of the scale effect of permanent firms comes from large firms with more than 100 employees (12.8%) whereas the intensity effect is exclusively driven by labour input adjustments in small firms (51.9%). This could point towards more flexibility in the production methods available to small firms compared to large firms. All of the new firms that contribute to the absorption

Table 9: Decomposition of changes in labour supply on the firm level, by industry type

1985-1995	Permanent scale		Permanent intensity		Net New firms		Ambiguous	Unemployment
	tradable	non-trad.	tradable	non-trad.	tradable	non-trad.		
<b>OLS</b>								
Labour Supply Growth	0.191*** (.036)		0.293*** (.050)		0.217*** (.026)		0.171*** (.044)	0.128*** (.020)
	0.130*** (.025)	0.061*** (.020)	0.170*** (.053)	0.123*** (.023)	0.116*** (.024)	0.101*** (.013)		
<b>IV</b>								
Labour Supply Growth	0.134** (.068)		0.311** (.128)		0.232*** (.044)		0.285** (.120)	0.039 (.049)
	0.028 (.052)	0.105** (.043)	0.346*** (.131)	-0.035 (.085)	0.073* (.044)	0.159*** (.037)		

Notes: All regressions use 612 observations and include a full set of skill and region fixed effects. Robust standard errors are reported in parentheses. Regressions are weighted by  $(1/N_r^{85} + 1/N_r^{95})^{-1/2}$  where  $N_r^t$  represents the overall labour force in region r in year t. Overall employment in 1985 was 8,513,067 (49.1%) in firms in tradable industries and 8,828,637 (50.9%) in firms in non-tradable industries. The first stage t-stat is 6.0. A (\*) denotes statistical significance at the 10% level, a (\*\*) at the 5% level and a (\*\*\*) at the 1% level.

of the changes in relative factor supplies are small firms which is to be expected since there are only around 4,200 newly established firms that have more than 100 employees in 1995 compared to around 700,000 newly established small firms (compare Table 1). The differential adjustment behaviour of small and large firms is of particular relevance in connection with the typical data sample selection in favour of large firms we discussed earlier. In an economy with predominantly small firms, focussing on large establishments may conceal some of the most important adjustment processes that locally take place in response to changes in relative factor supplies.

Table 10: Decomposition of changes in labour supply on the firm level, by firm size

1985-1995	Permanent scale		Permanent intensity		Net New firms		Ambiguous	Unemployment
	small	large	small	large	small	large		
<b>OLS</b>								
Labour Supply Growth	0.191*** (.036)		0.293*** (.050)		0.217*** (.026)		0.171*** (.044)	0.128*** (.020)
	0.074** (.030)	0.117*** (.024)	0.199*** (.017)	0.095* (.054)	0.177*** (.016)	0.040* (.021)		
<b>IV</b>								
Labour Supply Growth	0.134** (.068)		0.311** (.128)		0.232*** (.044)		0.285** (.120)	0.039 (.049)
	0.005 (.043)	0.128** (.051)	0.519*** (.058)	-0.208 (.143)	0.301*** (.034)	-0.070 (.043)		

Notes: All regressions use 612 observations and include a full set of skill and region fixed effects. Robust standard errors are reported in parentheses. Regressions are weighted by  $(1/N_r^{85} + 1/N_r^{95})^{-1/2}$  where  $N_r^t$  represents the overall labour force in region  $r$  in year  $t$ . Overall employment in 1985 was 8,482,928 (48.9%) in small firms and 8,858,776 (51.1%) in large firms. The first stage t-stat in the IV regressions is 6.0. A (\*) denotes statistical significance at the 10% level, a (\*\*) at the 5% level and a (\*\*\*) at the 1% level.

## 5 Firm Level Wage Responses

An important feature of the Heckscher-Ohlin-Samuelson model introduced in Section 4.1 and prerequisite for interpreting the observed changes in factor intensities as changes in production technology is that relative wages do not change in response to changes in local factor endowments. In Section 3 we have already shown that there is not much evidence of this for workers in tradable industries at the regional level. However, having moved the analysis to the firm level, it may be instructive to investigate to what extent relative wages have changed within firms in response to changes in their relative factor inputs. For that purpose, we estimate a model of the following form by OLS:

$$\Delta \log \left( \frac{w_i^f}{w_{medium}^f} \right) = controls + \gamma \Delta \log \left( \frac{N_i^f}{N_{medium}^f} \right) + \varepsilon_{if}, \quad (10)$$

where the dependent variable is the change in log relative wages in firm  $f$  with the base category being individuals with medium skill level,  $i \in (high, low)$ , and the key explanatory variable is the change in the relative factor inputs  $\Delta \log(N_i^f / N_{medium}^f)$  in firm  $f$ . We

Table 11: Wage adjustments to changes in relative firm-specific factor inputs

<b>1985-1995</b>	(1)	(2)
Manufacturing	0.001 (.011)	-0.004 (.011)
Tradable	0.008 (.011)	-0.012 (.010)
Non-tradable	-0.077*** (.012)	-0.081*** (.012)
All	-0.032*** (.009)	-0.048*** (.008)
Included fixed effects		
Education	✓	✓
Industry		✓
Education × industry		✓

Notes: Entries are coefficient estimates on the log change in firm-specific relative factor inputs, with medium skilled employment being the base category. Dependent variable is the corresponding change in log relative wages. The sample is restricted to permanent firms with more than 100 employees in the base year. There are 10,628 tradable firms of which 8,975 are manufacturing firms, 11,578 non-tradable firms, and 22,206 firms overall. All regressions use 204 West German labour market regions. Robust standard errors are reported in parentheses. Regressions are weighted by  $(1/N_j^{85} + 1/N_j^{95})^{-1/2}$  where  $N_j^t$  represents the firm size in terms of overall employment in year  $t$ . A (\*) denotes statistical significance at the 10% level, a (\*\*) at the 5% level and a (\*\*\*) at the 1% level.

estimate this model in five different specifications that vary by the set of fixed effects we include.

Table 11 reports estimates of  $\gamma$  for large permanent firms operating in different industry sectors. In the most basic formulation we only include a full set of skill group fixed effects.<sup>22</sup> The estimation results for this specification are reported in column (1). Overall, they reflect the empirical results we obtained from the regressions on the regional level in Section 3. There is no evidence of a correlation between changes in relative factor inputs and changes in relative wages for firms in manufacturing and other tradable indus-

<sup>22</sup>The starting point for such a specification of the regression model is a CES production function in which the log of the skill-specific productivity component of each of the three labour inputs is assumed to vary additively by firm, industry, region, and time. Allowing for a differential skill-specific time trend across industries gives rise to the inclusion of the additional set of fixed effects, as reported in column (2) of Table 11.

tries, but a significant negative correlation for firms operating in non-tradable industries with a point estimate of  $-0.077$ . All estimated correlations are robust to the inclusion of education $\times$ industry fixed effects. It is important to point out that these empirical results do not identify the elasticity of substitution between the different skill groups within firms since they do not take the potential endogeneity of the changes in firm-specific relative factor inputs into account. Moreover, under the reasonable assumption that labour is mobile between firms, changes in firm-specific relative factor inputs are not expected to lead to changes in relative wages since these are determined at the labour market rather than the firm level. If we do observe such wage changes, as for firms in non-tradable industries, they are likely to reflect unobserved differences in labour types across firms. Therefore the empirical results in Table 11 have to be interpreted as purely descriptive. They indicate that for firms in the tradable sector relative wages are fixed which, given the substantial adjustments in their relative factor inputs found in the previous section, points towards endogenous changes in production technologies. In the non-tradable case, relative wages are more flexible so that changes in relative factor inputs do not necessarily imply changes in technology. Firms could have moved along their isoquant of a given technology. As pointed out before, within firm adjustments in relative factor inputs are only interpretable as endogenous changes in technology if relative wages are fixed.

## **6 Conclusion**

In this paper, we use data on all individuals in the social security system that work in West Germany between 1985 and 1995 to analyse how industries and firms in local labour markets adjust to changes in the local labour supply due to immigration. Starting off with an industry level analysis à la Lewis (2004b), we find that about 62% of labour supply changes in a locality are absorbed within industry through changes in relative factor inputs while only about 20% are absorbed by changes in the industry mix, that is the relative scale of industries.

A further decomposition to the firm level reveals that only under strong assumptions can industry level changes in factor intensities be interpreted as changes in production technologies. Our firm level results imply that estimates obtained on the industry level are significantly overestimating the contribution of changes in production technology and that in particular the net creation of new firms is an important factor in absorbing changes in local labour supply, accommodating around 23% thereof of which about half can be interpreted as intensity adjustments. Our estimates show that in firms that exist in both 1985 and 1995 changes in relative factor intensities account for more than 31% of the overall changes in relative factor supplies while only around 13% are absorbed by changes in the scale of these firms. Adding the contributions from new firms, the firm level decomposition shows that overall around 44% of labour supply changes are absorbed within firm through changes in relative factor inputs and about 24% by changes in the output mix and the relative scale of firms. Our results therefore imply that, first, firms seem to adjust their production technologies according to the local labour supply mix and, second, changes in output mix are not a major source of adjustments to changes in local labour supply. There are some differences according to the size of a firm and the sector it operates in. Firms in tradable industries predominantly adjust through their factor intensities while firms in non-tradable industries predominantly adjust through their relative scales. Also, while large firms with more than 100 employees primarily adjust through their relative scales, small firms adjust through changes in their factor intensities.

To complement our results on firm-specific employment growth and factor intensities, our wage regressions show that firms in the tradable sector do not experience changes in relative wages in response to changes in relative factor inputs, pointing towards a change in production technology in these firms. Firms in the non-tradable sector on the other hand have experienced a decline in relative wages corresponding to the change in relative factor inputs. This could mean that these firms have moved along their isoquant, and thus not

necessarily changed their production technologies.

There are some interesting directions in which to take this analysis in the future. One aspect we have not addressed in this paper are the dynamics of the scale and intensity adjustment processes. It may well be that in the short run firms find it easier to increase their scale rather than switch to a new technology and that only after some time the changes in production technology are introduced and factor intensities adjusted to the changes in local labour supply. Also in terms of wages, one would expect the adjustment process to be dynamic. For instance, the Heckscher-Ohlin-Samuelson model predicts short-term changes in response to changes in local factor endowments which lead to positive profits being earned in those industries that use labour types intensively that have become cheaper. The positive profits then attract new entrants into these industries driving wages back up to their initial level in the long run. Analysing the dynamics of these adjustment processes would be helpful in fully understanding the way industries and firms behave when faced with a new labour supply situation. In this context, the analysis should also explicitly cover firm-level capital investments, both in terms of magnitude and type and in terms of timing, since they undoubtedly constitute an important additional component of the adjustment process to immigration.

Finally, we assume throughout this analysis, that output prices for tradable goods are set on the international market and that they are hence fixed from the perspective of the firms. Given that we are looking at a period of ten years, it would be interesting to analyse some data on relative output price changes, at least on the industry level, to see to what extent these changes may have contributed to the optimal choices of relative factor inputs within industries.

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## Appendix A Industry Characteristics

Table A-1: Industry characteristics

Industry	Total employment	% share employment	Average firm size	1995			Change 1985 - 1995						
				% low skill	% medium skill	% high skill	Wage low skill	Wage medium skill	Wage high skill	%Δ employment	%Δ low skill	%Δ medium skill	%Δ high skill
<b>Tradable industries</b>	7,856,455	46.8	20.5	24.1	67.4	8.5	63.9	83.2	131.1	-4.2	-28.1	9.9	64.3
Manufacture of electrical equipment	785,702	4.7	49.3	25.4	60.8	13.8	64.1	83.8	131.1	-8.0	-28.3	10.8	42.0
Financial intermediation and insurance industry	751,137	4.5	24.3	13.0	78.1	8.9	57.5	95.0	128.7	10.8	-28.9	1.8	76.5
Manufacture of motor vehicles	571,270	3.4	283.4	25.6	67.1	7.4	82.8	94.5	131.1	-7.8	-33.0	16.5	71.6
Manufacture of machinery	531,331	3.2	42.5	15.4	76.7	7.9	64.6	87.6	131.1	-8.5	-34.0	6.7	65.1
Manufacture of chemicals and chemical products	484,372	2.9	139.8	21.0	66.8	12.2	73.9	96.9	131.1	-11.3	-32.1	9.9	47.7
Manufacture of earth-moving equipment	330,916	2.0	40.1	35.1	61.4	3.5	64.8	79.1	130.3	2.3	-20.3	13.7	79.9
Legal advice and business consulting	324,067	1.9	5.9	14.5	66.9	18.6	17.9	66.0	118.9	60.5	-33.4	-1.0	74.9
Architecture and engineering firms	286,138	1.7	7.4	8.2	57.4	34.5	33.1	83.0	122.7	61.0	-29.7	-7.2	29.7
Manufacture of gears	284,228	1.7	55.2	19.3	72.0	8.7	67.1	85.5	131.1	-9.2	-27.3	7.4	35.5
Manufacture of food products	282,796	1.7	14.4	29.4	68.4	2.2	52.1	62.8	129.7	-4.6	-25.9	15.7	83.2
Manufacture of furniture	281,252	1.7	10.8	25.9	72.8	1.4	54.9	73.5	106.3	4.4	-14.1	5.3	72.5
Manufacture of plastic products	253,564	1.5	40.4	37.5	58.7	3.8	61.6	76.0	129.0	22.4	-20.3	15.7	70.7
Printing	173,063	1.0	16.1	22.1	75.3	2.6	64.5	88.1	122.9	-0.9	-15.7	4.1	78.9
Manufacture of tanks and containers	169,122	1.0	25.3	18.3	76.1	5.6	65.7	80.5	131.1	4.8	-21.7	4.4	49.7
Precision mechanics and optical equipment	165,509	1.0	14.7	23.8	70.2	6.0	52.4	75.9	130.8	-9.1	-29.0	11.7	65.2
Manufacture of stones and mortars	164,176	1.0	18.4	29.9	66.3	3.8	75.1	84.3	130.8	1.4	-20.2	10.7	46.3
Manufacture of basic iron and steel	154,829	0.9	217.8	32.6	62.2	5.2	74.2	84.4	131.1	-36.4	-19.8	11.7	41.4
Manufacture of ventilation and heating equipment	152,202	0.9	10.9	17.9	78.9	3.2	18.1	74.7	123.5	18.5	-20.7	5.3	29.5
Real estate	147,544	0.9	5.6	12.1	75.5	12.4	54.4	83.3	130.6	59.8	-24.6	0.7	37.8
Manufacture of paper products	135,894	0.8	55.8	37.7	58.7	3.6	65.6	81.3	130.9	-0.4	-22.6	19.6	63.4
Meat processing	128,711	0.8	8.7	27.1	72.3	0.5	46.8	57.1	109.6	-17.7	-27.0	15.6	80.3
Forging, stamping and pressing of steel	127,566	0.8	26.4	37.3	60.1	2.5	67.0	80.0	130.3	2.8	-17.4	13.1	55.4
Manufacture of textiles	126,481	0.8	39.5	43.1	53.9	3.0	56.3	70.6	115.7	-39.6	-21.3	23.3	94.0
Mining and quarrying	125,827	0.8	299.0	29.9	62.9	7.2	74.5	81.8	130.5	-42.5	-12.4	3.7	39.0
Manufacture of beverages and tobacco products	83,629	0.5	35.2	23.9	71.9	4.2	68.8	84.3	130.8	-16.0	-20.5	6.9	56.0
Manufacture of apparel	82,768	0.5	17.7	33.2	65.1	1.8	46.1	56.5	97.4	-51.6	-24.7	17.6	183.9
Shipbuilding and manufacture of aircraft	77,641	0.5	129.3	12.0	71.1	16.8	70.7	93.4	131.1	-12.7	-36.1	3.3	36.8
Casting of metals	73,083	0.4	67.4	41.2	55.9	2.9	74.1	84.8	131.1	-19.3	-15.4	12.9	66.3
Manufacture of rubber products	71,683	0.4	76.8	39.4	54.6	6.0	70.4	78.8	130.5	-22.0	-21.3	16.9	86.7
Locksmith's, grinding and welding shops	57,400	0.3	6.9	21.1	77.4	1.5	47.9	69.7	108.2	14.1	-30.4	12.4	81.3
Manufacture of glass products	53,978	0.3	63.7	35.6	59.5	4.9	66.3	76.5	130.0	-9.4	-25.3	19.7	85.4
Manufacture of wood	53,258	0.3	5.7	14.6	74.6	10.8	44.6	78.4	102.6	48.7	-20.3	0.0	51.7
Advertising	45,838	0.3	46.3	47.1	48.9	3.9	57.7	71.5	130.0	-20.6	-16.7	18.7	77.1
Manufacture of ceramic products	38,793	0.2	86.3	41.0	55.6	3.4	73.7	84.4	131.1	-22.5	-17.1	14.5	71.2
Cold drawing and rolling	38,625	0.2	34.1	17.0	62.1	20.9	65.6	94.7	131.1	-41.0	-34.3	12.3	10.9
Manufacture of data processing equipment	38,360	0.2	99.7	48.0	48.6	3.5	49.2	76.7	130.5	4.6	-10.3	8.7	86.8
Manufacture of confectionery	29,099	0.2	14.8	44.2	54.3	1.5	57.5	69.9	110.0	-3.0	-13.0	12.7	47.1
Manufacture of other wood products	23,274	0.1	10.4	42.2	55.1	2.7	52.3	62.1	117.6	-48.3	-29.8	40.2	389.0
Manufacture of footwear	18,334	0.1	18.3	39.6	58.3	2.1	53.9	71.6	109.5	-14.2	-17.9	15.2	79.9
Manufacture of toys and musical instruments	16,481	0.1	5.7	30.0	69.2	0.8	47.3	60.9	88.8	0.2	-12.9	6.6	23.8
Upholstery	15,586	0.1	14.6	42.8	55.3	1.9	49.5	63.5	112.0	-36.5	-20.6	22.1	138.0
Manufacture of leather products	14,451	0.1	7.2	25.6	73.2	1.3	45.1	63.5	107.4	-22.8	-24.2	11.9	36.9
Manufacture of jewellery	4,964	0.0	4.1	30.3	64.3	5.4	37.6	60.5	106.7	5.9	-24.4	14.6	41.4

continued on next page

Industry	1995										Change 1985 - 1995				
	Total employment	% share employment	Average firm size	% low skill	% medium skill	% high skill	Wage low skill	Wage medium skill	Wage high skill	%Δ employment	%Δ low skill	%Δ medium skill	%Δ high skill		
<b>Non-tradable industries</b>	8,915,161	53.2	9.9	21.5	71.7	6.8	49.2	72.5	118.0	7.5	-22.0	6.0	41.8		
Retail	2,178,444	13.0	7.9	17.5	78.6	3.9	47.4	67.2	122.9	5.8	-24.3	5.4	70.4		
Health	1,032,287	6.2	9.7	19.3	69.8	10.9	27.6	69.2	131.1	18.6	-25.4	6.6	26.2		
Main construction trade	729,719	4.4	16.3	26.1	69.7	4.2	66.9	81.1	131.1	-3.4	-6.6	1.2	33.2		
Public administration	664,524	4.0	41.6	69.9	69.9	11.3	65.1	75.0	111.5	0.1	-27.9	6.8	32.7		
Building installation	429,069	2.6	6.8	22.1	77.2	0.8	18.6	70.4	99.8	9.2	-19.4	6.9	89.7		
Hotels and restaurants	319,950	1.9	4.4	38.4	60.7	0.8	31.3	48.0	77.6	-0.8	-17.3	14.6	66.1		
Repair of motor vehicles	271,008	1.6	9.9	21.5	77.7	0.8	16.5	70.1	118.9	4.3	-26.2	10.6	40.0		
Schools and universities	256,238	1.5	21.3	13.1	49.1	37.8	35.0	79.7	111.2	5.0	-34.6	-3.5	29.8		
Residential homes	251,413	1.5	27.4	26.4	67.5	6.1	54.9	72.4	94.3	46.8	-28.7	16.1	25.6		
Road traffic	243,443	1.5	8.1	22.8	76.0	1.2	67.8	73.7	115.1	18.4	-19.8	7.3	54.2		
Electricity, gas and water supply	221,068	1.3	65.3	11.2	79.0	9.8	72.9	99.4	131.1	0.8	-34.3	4.0	39.9		
Goods transportation on the road	215,566	1.3	16.2	25.3	73.1	1.6	62.9	73.8	121.7	28.5	-10.6	3.6	39.6		
Other services	200,717	1.2	15.1	28.3	67.0	4.7	40.0	56.1	111.1	103.8	5.0	-2.5	8.2		
Political parties	186,505	1.1	11.3	19.4	60.9	19.7	46.4	76.0	101.7	50.5	-18.7	1.7	20.8		
Defence, public security and law and order	165,486	1.0	94.1	29.4	67.7	2.9	67.3	74.1	100.2	-34.9	-12.2	3.8	123.3		
Other education	160,029	1.0	6.8	17.5	73.8	8.6	32.4	69.4	91.5	27.4	-27.3	7.7	18.5		
Social security, extra-territorial organisations	154,674	0.9	26.6	13.8	80.0	6.2	60.0	79.2	106.5	19.4	-25.4	3.4	51.1		
Carpentry and tiling	115,714	0.7	8.1	29.6	69.8	0.6	55.2	74.3	98.1	15.9	-4.3	1.7	32.5		
Post	114,437	0.7	33.5	15.2	84.1	0.6	24.5	77.1	130.5	-10.1	-50.7	22.6	28.9		
Hairdresser	105,031	0.6	3.1	25.3	74.6	0.1	12.1	36.8	44.1	-28.4	-33.9	20.9	84.0		
Publishing and press	104,903	0.6	18.6	13.2	71.4	15.4	67.2	93.7	120.7	9.7	-26.3	-2.1	68.7		
Aviation	104,583	0.6	13.8	18.6	75.8	5.7	73.8	82.2	129.9	29.2	-12.3	2.3	19.3		
Sanitation and refuse disposal	95,256	0.6	18.6	37.2	58.2	4.6	73.5	80.6	115.8	41.8	-21.9	14.4	200.9		
Cleaning	94,256	0.6	7.5	52.2	46.7	1.0	42.5	66.7	105.1	23.1	-3.5	3.0	93.7		
Horticulture and viniculture	93,941	0.6	5.5	40.6	57.3	2.1	46.5	55.7	79.6	5.8	-15.8	13.9	43.7		
Railways	92,604	0.6	91.3	36.2	62.1	1.7	71.4	78.2	103.8	-27.3	-21.2	15.5	565.2		
Churches	78,910	0.5	8.3	12.6	60.7	26.7	46.6	75.6	109.5	12.9	-29.0	1.5	18.9		
Activities of membership organisations	71,773	0.4	11.7	10.6	68.8	20.6	58.8	85.7	129.7	1.3	-47.1	4.7	44.3		
Art, theatre, film, radio and television	58,072	0.3	17.3	12.3	67.4	20.2	70.9	89.2	124.8	11.2	-20.7	-1.8	28.5		
Auctioning and pawnbroking	28,540	0.2	6.5	17.2	78.6	4.2	54.5	75.1	125.6	40.8	-12.1	1.9	27.6		
Shipping	28,108	0.2	16.3	14.7	73.5	11.7	84.6	91.8	124.8	-11.4	-35.5	-0.1	229.9		
Private households	16,543	0.1	1.2	36.5	61.5	2.0	33.3	43.7	65.1	-43.1	-34.7	42.4	112.7		
Forestry and hunting	16,132	0.1	5.6	28.6	70.0	1.4	54.8	74.4	98.1	-40.2	-30.6	20.8	65.8		
Photographic activities	15,567	0.1	6.7	21.9	75.9	2.2	31.8	63.9	97.4	-4.4	-18.1	5.3	86.5		
Fishing	651	0.0	2.8	26.9	71.9	1.2	29.4	58.2	88.0	-37.5	-26.9	17.7	-41.9		

Source: IAB

## Appendix B Decompositions I

The change in skill-specific labour supply in a local labour market can be decomposed in the following way:

$$\Delta L_i = \sum_j \Delta N_{ij} + \Delta U_i.$$

Dividing through by the labour supply of skill group  $i$  in the base period (denoted by the subscript 0) and then expanding we get

$$\begin{aligned} \frac{\Delta L_i}{L_{i0}} &= \sum_j \frac{\Delta N_{ij}}{L_{i0}} + \frac{\Delta U_i}{L_{i0}} \\ &= \sum_j \frac{N_{ij0}}{L_{i0}} \frac{\Delta N_{ij}}{N_{ij0}} + \frac{U_{i0}}{L_{i0}} \frac{\Delta U_i}{U_{i0}} \\ &= \sum_j s_{ij0} \% \Delta N_{ij} + s_{iu0} \% \Delta U_i. \end{aligned} \tag{B-1}$$

Now let  $M_j$  be a measure of the size of an industry. Then we have

$$N_{ij} = M_j \left( \frac{N_{ij}}{M_j} \right).$$

This can be decomposed into three terms:

$$\begin{aligned} \% \Delta N_{ij} &= \frac{\Delta N_{ij}}{N_{ij0}} = \frac{M_j N_{ij}}{N_{ij0} M_j} - \frac{M_{j0} N_{ij0}}{N_{ij0} M_{j0}} = \frac{M_j N_{ij}}{N_{ij0} M_j} - 1 \\ &= \frac{N_{ij} M_{j0}}{M_j N_{ij0}} + \frac{(M_j - M_{j0}) N_{ij}}{M_j N_{ij0}} - 1 \\ &= \frac{M_j - M_{j0}}{M_{j0}} + \frac{N_{ij} M_{j0}}{M_j N_{ij0}} - 1 + \frac{M_j - M_{j0}}{M_{j0}} \left( \frac{N_{ij} M_{j0}}{M_j N_{ij0}} - 1 \right) \\ &= \left( \frac{M_j - M_{j0}}{M_{j0}} \right) + \left( \frac{\frac{N_{ij}}{M_j} - \frac{N_{ij0}}{M_{j0}}}{\frac{N_{ij0}}{M_{j0}}} \right) + \left( \frac{M_j - M_{j0}}{M_{j0}} \right) \left( \frac{\frac{N_{ij}}{M_j} - \frac{N_{ij0}}{M_{j0}}}{\frac{N_{ij0}}{M_{j0}}} \right) \\ &= \% \Delta M_j + \% \Delta \left( \frac{N_{ij}}{M_j} \right) + \% \Delta M_j \cdot \% \Delta \left( \frac{N_{ij}}{M_j} \right), \end{aligned}$$

which, by substitution into Equation B-1, yields the stated decomposition.

## Appendix C Decompositions II

The change in skill-specific labour supply in a local labour market can be decomposed in the following way:

$$\begin{aligned}\Delta L_i &= \sum_j \Delta N_{ij} + \Delta U_i \\ &= \sum_j (\sum_{f^p} \Delta N_{ijf^p} + \sum_{f^n} \Delta N_{ijf^n} + \sum_{f^o} \Delta N_{ijf^o}) + \Delta U_i.\end{aligned}$$

Dividing through by the labour supply of skill group  $i$  in the base period (denoted by the subscript 0) and then expanding we get

$$\begin{aligned}\frac{\Delta L_i}{L_{i0}} &= \sum_j \left( \sum_{f^p} \frac{\Delta N_{ijf^p}}{L_{i0}} + \sum_{f^n} \frac{\Delta N_{ijf^n}}{L_{i0}} + \sum_{f^o} \frac{\Delta N_{ijf^o}}{L_{i0}} \right) + \frac{\Delta U_i}{L_{i0}} \\ &= \sum_j \sum_{f^p} \frac{N_{ij0}}{L_{i0}} \frac{N_{ijf^p}}{N_{ij0}} \frac{\Delta N_{ijf^p}}{N_{ijf^p_0}} + \sum_j \sum_{f^n} \frac{\Delta N_{ijf^n}}{L_{i0}} + \sum_j \sum_{f^o} \frac{N_{ij0}}{L_{i0}} \frac{N_{ijf^o}}{N_{ij0}} \frac{\Delta N_{ijf^o}}{N_{ijf^o_0}} + \frac{U_{i0}}{L_{i0}} \frac{\Delta U_i}{U_{i0}} \\ &= \sum_j \sum_{f^p} s_{ij0} s_{ijf^p_0} (\% \Delta N_{ijf^p}) + \sum_j \sum_{f^n} \frac{\Delta N_{ijf^n}}{L_{i0}} + \sum_j \sum_{f^o} (-1) s_{ij0} s_{ijf^o_0} + s_{iu0} \% \Delta U_i.\end{aligned}$$

Now let  $M_{jf}$  be a measure of the size of a firm. Then we have

$$N_{ijf} = M_{jf} \left( \frac{N_{ijf}}{M_{jf}} \right).$$

For all permanent firms (and only for these firms) this can be decomposed into three terms:

$$\begin{aligned}\% \Delta N_{ijf} &= \frac{\Delta N_{ijf}}{N_{ijf_0}} = \frac{M_{jfp} N_{ijfp}}{N_{ijf_0} M_{jfp}} - \frac{M_{jf_0} N_{ijf_0}}{N_{ijf_0} M_{jfp}} = \frac{M_{jfp} N_{ijfp}}{N_{ijf_0} M_{jfp}} - 1 \\ &= \frac{N_{ijfp} M_{jfp}}{M_{jfp} N_{ijf_0}} + \frac{(M_{jfp} - M_{jf_0}) N_{ijfp}}{M_{jfp} N_{ijf_0}} - 1 \\ &= \frac{M_{jfp} - M_{jf_0}}{M_{jf_0}} + \frac{N_{ijfp} M_{jfp}}{M_{jfp} N_{ijf_0}} - 1 + \frac{M_{jfp} - M_{jf_0}}{M_{jf_0}} \left( \frac{N_{ijfp} M_{jfp}}{M_{jfp} N_{ijf_0}} - 1 \right) \\ &= \left( \frac{M_{jfp} - M_{jf_0}}{M_{jf_0}} \right) + \left( \frac{\frac{N_{ijfp}}{M_{jfp}} - \frac{N_{ijf_0}}{M_{jf_0}}}{\frac{N_{ijf_0}}{M_{jf_0}}} \right) + \left( \frac{M_{jfp} - M_{jf_0}}{M_{jf_0}} \right) \left( \frac{\frac{N_{ijfp}}{M_{jfp}} - \frac{N_{ijf_0}}{M_{jf_0}}}{\frac{N_{ijf_0}}{M_{jf_0}}} \right) \\ &= \% \Delta M_{jfp} + \% \Delta \left( \frac{N_{ijfp}}{M_{jfp}} \right) + \% \Delta M_{jfp} \cdot \% \Delta \left( \frac{N_{ijfp}}{M_{jfp}} \right).\end{aligned}$$

## Appendix D Decompositions III

Here we show how one can transform the Lewis decomposition, which simply gives the contributions of permanent, new and old firms of the measured between and within industry changes (see Equations 5 and 6), into the new decomposition which accurately reflects between and within firm changes.

The identity for the between industry effect of permanent firms:

$$\begin{aligned}
 \sum_j \sum_{f^p} s_{ij_0} \left( \frac{M_{jfp} - M_{jf_0^p}}{M_{j_0}} \right) &= \sum_j \sum_{f^p} s_{ij_0} \left( \frac{M_{jfp}}{M_{j_0}} \right) \left( \frac{M_{jfp} - M_{jf_0^p}}{M_{jf_0^p}} \right) \\
 &= \sum_j \sum_{f^p} s_{ij_0} \left( \frac{M_{jfp}}{M_{j_0}} + \frac{N_{ijfp}}{N_{ij_0}} - \frac{N_{ijfp}}{N_{ij_0}} \right) \left( \frac{M_{jfp} - M_{jf_0^p}}{M_{jf_0^p}} \right) \\
 &= \sum_j \sum_{f^p} s_{ij_0} s_{ijfp} \cdot \% \Delta M_{jfp} - \sum_j \sum_{f^p} s_{ij_0} \left( \frac{N_{ijfp}}{N_{ij_0}} - \frac{M_{jfp}}{M_{j_0}} \right) \left( \frac{M_{jfp} - M_{jf_0^p}}{M_{jf_0^p}} \right)
 \end{aligned}$$

The identity for the within industry effect of permanent firms:

$$\begin{aligned}
 \sum_j \sum_{f^p} s_{ij_0} \left( \frac{\frac{N_{ijfp}}{M_j} - \frac{N_{ijfp}}{M_{j_0}}}{\frac{N_{ij_0}}{M_{j_0}}} \right) &= \sum_j \sum_{f^p} s_{ij_0} \left( \frac{N_{ijfp}}{M_j} \right) - \sum_j \sum_{f^p} s_{ij_0} \left( \frac{N_{ijfp}}{M_{j_0}} \right) \\
 &= \sum_j \sum_{f^p} s_{ij_0} \frac{M_{jfp}}{M_{jfp}} \left( \frac{N_{ijfp}}{M_j} \right) \left( \frac{N_{ijfp}}{M_{j_0}} \right) - \sum_j \sum_{f^p} s_{ij_0} \frac{M_{jfp}}{M_{jfp}} \left( \frac{N_{ijfp}}{M_{j_0}} \right) \left( \frac{N_{ijfp}}{M_{j_0}} \right) \\
 &= \sum_j \sum_{f^p} s_{ij_0} \frac{M_{jfp}}{M_j} \left( \frac{N_{ijfp}}{M_{j_0}} \right) \left( \frac{N_{ijfp}}{M_{jfp}} \right) - \sum_j \sum_{f^p} s_{ij_0} \frac{M_{jfp}}{M_{j_0}} \left( \frac{N_{ijfp}}{M_{j_0}} \right) \left( \frac{N_{ijfp}}{M_{jfp}} \right) \\
 &= \sum_j \sum_{f^p} s_{ij_0} s_{ijfp} \left( \frac{M_{jfp}}{M_{j_0}} \right) \left( \frac{N_{ijfp}}{M_{jfp}} \right) - \sum_j \sum_{f^p} s_{ij_0} s_{ijfp} \cdot 1 \cdot \left( \frac{M_{jfp}}{M_{j_0}} \right) \left( \frac{N_{ijfp}}{M_{jfp}} \right) \\
 &= \sum_j \sum_{f^p} s_{ij_0} s_{ijfp} \left( 1 + \frac{M_{jfp} - M_j}{M_{j_0}} \right) \left( \frac{N_{ijfp}}{M_{jfp}} \right) - \sum_j \sum_{f^p} s_{ij_0} s_{ijfp} \left( \frac{N_{ijfp}}{M_{jfp}} \right) \\
 &= \sum_j \sum_{f^p} s_{ij_0} s_{ijfp} \cdot \% \Delta \left( \frac{N_{ijfp}}{M_{jfp}} \right) + \sum_j \sum_{f^p} s_{ij_0} s_{ijfp} \left( \frac{N_{ijfp}}{M_{jfp}} \right) \cdot \left( \frac{M_{jfp} - M_j}{M_{j_0}} \right)
 \end{aligned}$$

The identity for new firms (for which  $N_{ijf_0^n} = 0$ ):

$$\begin{aligned}
\sum_j \sum_{f^n} \frac{\Delta N_{ijf^n}}{L_{i_0}} &= \sum_j \sum_{f^n} s_{ij_0} \frac{N_{ijf^n}}{N_{ij_0}} \\
&= \sum_j \sum_{f^n} s_{ij_0} \frac{M_{j_0}}{M_j} \frac{M_j}{M_{j_0}} \frac{N_{ijf^n}}{N_{ij_0}} \\
&= \sum_j \sum_{f^n} s_{ij_0} \left( \frac{\frac{N_{ijf^n}}{M_j}}{\frac{N_{ij_0}}{M_{j_0}}} \right) \frac{M_j}{M_{j_0}} \\
&= \sum_j \sum_{f^n} s_{ij_0} \left( \frac{\frac{N_{ijf^n}}{M_j}}{\frac{N_{ij_0}}{M_{j_0}}} \right) \left( 1 + \frac{M_j - M_{j_0}}{M_{j_0}} \right) + \sum_j \sum_{f^n} s_{ij_0} \frac{M_{jf^n} - M_{jf_0^n}}{M_{j_0}} - \sum_j \sum_{f^n} s_{ij_0} \frac{M_{jf^n} - M_{jf_0^n}}{M_{j_0}} \\
&= \sum_j \sum_{f^n} s_{ij_0} \left( \frac{\frac{N_{ijf^n}}{M_j}}{\frac{N_{ij_0}}{M_{j_0}}} \right) + \sum_j \sum_{f^n} s_{ij_0} \left( \frac{M_{jf^n}}{M_{j_0}} \right) + \sum_j \sum_{f^n} s_{ij_0} \left[ \left( \frac{\frac{N_{ijf^n}}{M_j}}{\frac{N_{ij_0}}{M_{j_0}}} \right) \frac{M_j - M_{j_0}}{M_{j_0}} - \frac{M_{jf^n}}{M_{j_0}} \right]
\end{aligned}$$

The identity for old firms (for which  $N_{ijf_0^o} = 0$ ):

$$\begin{aligned}
-\sum_j \sum_{f^o} s_{ij_0} s_{ijf_0^o} &= -\sum_j \sum_{f^o} s_{ij_0} \frac{N_{ijf_0^o}}{N_{ij_0}} \\
&= -\sum_j \sum_{f^o} s_{ij_0} \frac{M_{j_0}}{M_j} \frac{N_{ijf_0^o}}{N_{ij_0}} \\
&= -\sum_j \sum_{f^o} s_{ij_0} \left( \frac{\frac{N_{ijf_0^o}}{M_{j_0}}}{\frac{N_{ij_0}}{M_{j_0}}} \right) \\
&= -\sum_j \sum_{f^o} s_{ij_0} \left( \frac{\frac{N_{ijf_0^o}}{M_j}}{\frac{N_{ij_0}}{M_{j_0}}} \right) + \sum_j \sum_{f^o} s_{ij_0} \frac{M_{jf_0^o} - M_{jf_0^o}}{M_{j_0}} - \sum_j \sum_{f^o} s_{ij_0} \frac{M_{jf_0^o} - M_{jf_0^o}}{M_{j_0}} \\
&= -\sum_j \sum_{f^o} s_{ij_0} \left( \frac{\frac{N_{ijf_0^o}}{M_j}}{\frac{N_{ij_0}}{M_{j_0}}} \right) - \sum_j \sum_{f^o} s_{ij_0} \left( \frac{M_{jf_0^o}}{M_{j_0}} \right) + \sum_j \sum_{f^o} s_{ij_0} \left( \frac{M_{jf_0^o}}{M_{j_0}} \right)
\end{aligned}$$

To sum up, we have:

$$\underbrace{\sum_j \sum_{f^p} s_{ij_0} \left( \frac{M_{jfp} - M_{jf_0^p}}{M_{j_0}} \right)}_{\text{permanent firms contribution industry scale effect}} = \underbrace{\sum_j \sum_{f^p} s_{ij_0} s_{ijf_0^p} \cdot \% \Delta M_{jfp}}_{\text{permanent firms scale effect}} - \underbrace{\sum_j \sum_{f^p} s_{ij_0} \left( \frac{N_{ijf_0^p}}{N_{i_0}} - \frac{M_{jfp}}{M_{j_0}} \right) \left( \frac{M_{jfp} - M_{jf_0^p}}{M_{j_0}} \right)}_{\text{residual term}}$$

$$\underbrace{\sum_j \sum_{f^p} s_{ij_0} \left( \frac{\frac{N_{ijfp}}{M_j} - \frac{N_{ijf_0^p}}{M_{j_0}}}{\frac{N_{ij_0}}{M_{j_0}}} \right)}_{\text{permanent firms contribution industry intensity effect}} = \underbrace{\sum_j \sum_{f^p} s_{ij_0} s_{ijf_0^p} \cdot \% \Delta \left( \frac{N_{ijfp}}{M_{jfp}} \right)}_{\text{permanent firms intensity effect}} + \underbrace{\sum_j \sum_{f^p} s_{ij_0} s_{ijf_0^p} \left( \frac{\frac{N_{ijfp}}{N_{ijf_0^p}}}{\frac{M_{jfp}}{M_{j_0^p}}} \cdot \frac{(M_{jfp} - M_j)}{M_{j_0}} \right)}_{\text{residual term}}$$

$$\underbrace{\sum_j \sum_{f^n} s_{ij_0} \left( \frac{M_{jfn}}{M_{j_0}} \right)}_{\text{new firms contribution industry scale effect}} + \underbrace{\sum_j \sum_{f^n} s_{ij_0} \left( \frac{\frac{N_{ijfn}}{M_j}}{\frac{N_{ij_0}}{M_{j_0}}} \right)}_{\text{new firms contribution industry intensity effect}} = \underbrace{\sum_j \sum_{f^n} \frac{\Delta N_{ijfn}}{L_{i_0}}}_{\text{new firms contribution}} - \underbrace{\sum_j \sum_{f^n} s_{ij_0} \left[ \left( \frac{\frac{N_{ijfn}}{M_j}}{\frac{N_{ij_0}}{M_{j_0}}} \right) \frac{M_j - M_{j_0}}{M_{j_0}} - \frac{M_{jfn}}{M_{j_0}} \right]}_{\text{residual term}}$$

$$\underbrace{-\sum_j \sum_{f^o} s_{ij_0} \left( \frac{M_{jfo}}{M_{j_0}} \right)}_{\text{old firms contribution industry scale effect}} - \underbrace{\sum_j \sum_{f^o} s_{ij_0} \left( \frac{\frac{N_{ijfo}}{M_{j_0}}}{\frac{N_{ij_0}}{M_{j_0}}} \right)}_{\text{old firms contribution industry intensity effect}} = \underbrace{-\sum_j \sum_{f^o} s_{ij_0} s_{ijf_0^o}}_{\text{old firms contribution}} - \underbrace{\sum_j \sum_{f^o} s_{ij_0} \left( \frac{M_{jfo}}{M_{j_0}} \right)}_{\text{residual term}}$$