

Long-run Asymmetries in Labor Demand: Estimating Wage Elasticities of Labor Demand Using a Fractional Panel Probit Model

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Abstract. Models of labor demand usually use cost or production functions to derive profit-maximizing firm performance. These models often rely on the assumption of symmetrical behavior, i.e., the response to a positive or negative wage shock of the same relative size is identical to the shock, and the estimated labor demand elasticities are the same for increasing and decreasing employment. However, behavioral economics models like loss aversion and endowment effects question the assumption of symmetry in labor demand. In addition, the influence of a labor shortage should be reflected in the investigations. Estimations of Fractional Panel Probit models for three different skill levels are applied to evaluate these findings with a large panel of German establishments. The results indicate asymmetrical structures for long-run own-wage elasticities and for some cross-wage elasticities, putting some doubt on the assumption of strict rationality in labor demand and indicating the influence of labor shortages.

1. Introduction

Labor demand analysis commonly relies on the use of very strong assumptions about the behavior of employers and employees. In particular, the production or cost functions that are normally used to derive optimal labor demand impose that the firms act as rational agents, maximizing their profits under the conditions of the actual markets. Optimal labor demand is, therefore, achieved when marginal labor costs equal marginal revenue from selling goods (cf. Hamermesh, 1993). The main target of the paper at hand is to question some of these restrictive assumptions. Especially, the functional form and the assumption of rational behavior imply symmetry in the changes of employment for wage positive or negative changes of the same size. Unlike in other studies, the case of asymmetry here is not analyzed within a framework of dynamic labor demand models, where different adjustment costs for hirings and dismissals lead to asymmetries in the adjustment

This study used data of the IAB Establishment Panel from the Institute for Employment Research (IAB). Data access was provided via on-site use at the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research and/or remote data access.

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process. The subsequent analysis relies on the calculation of long-run changes of employment according to increasing or decreasing wages.

The analysis of labor demand usually identifies own- and cross-wage elasticities, indicating relative movements of labor demand from relative wage changes. Normally, the results show that the own-wage elasticities are negative, because higher wages increase the costs of production. Cross-wage elasticities show complementary and substitutional structures of labor demand between different qualifications. The assumption of rationality further implies that these elasticities are symmetrical; i.e., positive or negative wage shocks of the same size should lead to identical quantitative long-run effects in absolute terms. Although adjustment processes might be different for increasing or decreasing employment for specific reasons, the new long-run equilibrium is independent from the velocity of adjustments.

However, there are a few situations that prevent symmetrical behavior. Long-term adjustment processes that impede reaching the new equilibrium completely before a new shock arises, labor shortages that inhibit new personnel hiring, and, individual behavior that questions the assumption of strict rationality. Insights from behavioral economics suggest that individuals are not strictly rational in their actions. The ideal way to analyze these biases would be to develop a separate methodological framework using instruments directly indicating the influence of other explanations. Unfortunately, the panel data used here do not contain these kinds of variables. Moreover, the effects of behavioral explanations are often indicated as biases from standard economic models. Therefore, we will start discussing some implications of the standard labor demand model and also some reasons, why these implications may not occur. One of the explanations, but not the only one, is to assume some loss aversion from the framework of behavioral economics. After the theoretical discussion, we applied a fractional panel probit regression model to estimate labor demand with the extension of possible biases from the standard assumptions. After controlling for other possibilities of asymmetrical labor demand, we will propose that the remaining effect belongs to behavioral explanations like loss aversion. If asymmetries are detected, this could have further impact on the use of labor market policies as growing and shrinking wages of the same absolute value probably have a different impact on the relative change in employment.

The subsequent analysis uses the IAB Establishment Panel, a large panel dataset from German establishments. The survey is based on a stratified random sample and covers the period from 2004 to 2014. The unbalanced data contains about 16,000 observations each year. In particular, a fractional panel probit model (Wooldridge, 2010a,b) for three different skill levels is applied to estimate labor within a system of Seemingly Unrelated Regressions (SUR). Initial results support the assumption of asymmetrical own- and cross-wage elasticities. From the subsequent discussion and regression results, we will argue that this is probably due to the bounded rationality of the firms' decisions about hirings and firings. Especially, the long-run own-wage elasticities seem to be less negative for all skill levels when employment of the observed qualification increases. This means that the downward adjustment is larger (not necessarily faster) when wages increase versus an upward adjustment for a corresponding decrease in wages of the same absolute value. In addition, there is a substitutional relationship between medium- and high-skilled workers in the demand for the latter group, whereas there is no effect of changes in the remuneration of high-skilled workers on the demand for medium-skilled workers. Thus, employers are willing to change the number of skilled workers when labor costs of medium-skilled workers grow and fall, but the number of medium-skilled workers is not affected by the wages of high-skilled workers.

The research contributes to the rich literature on labor demand in two different ways. First, it questions some assumptions that are usually used to derive labor demand from profit-maximizing respective cost-minimizing behavior of the firms. Especially, the application of insights from behavioral economics is a new aspect in the research. Secondly, the paper introduces fractional panel probit estimations for different skill levels. These types of models efficiently estimate share equations, even if the shares are zero or one, which is often the case when looking at different skills at the establishment level.

The remainder of the paper is organized as follows. The next section provides some information about labor demand theory and discusses the reasons for asymmetrical labor demand. Section 3 introduces the fractional panel probit regression as the empirical model of the investigations and provides information about the used data, the IAB establishment panel. Section 4 contains the results of the empirical estimations, whereas the final section summarizes the outcome of the research.

2. Theoretical considerations and previous studies

Labor demand is often derived from a functional framework of cost or production functions. Next to Cobb–Douglas, generalized Leontief, and CES production functions, the translog cost function is frequently applied in the literature (Berndt and Khaled, 1979; Falk and Koebel, 2004; Freier and Steiner, 2010). The following analysis will rely on translog cost functions without restrictions of the results because of its very common structure containing the other functions as special cases. The outcome of the model implies symmetry in behavior, crucially because of its functional form. In the subsequent section, we will discuss several reasons why symmetrical long-run labor demand elasticities possibly do not occur in the empirical results. As mentioned in the introduction, we will focus on three different causes: dynamic long-term adjustment processes, labor shortages, and bounded rationality.

The assumption of time-consuming dynamic adjustment processes proposes that it takes time to increase or decrease the firms' employment. This is in line with the use of a quadratic adjustment cost function, where the marginal costs of hiring and firing increase with the number of affected jobs (Hamermesh, 1993). When adjustment costs increase, e.g., because of strict employment protection rules (cf. Nickell, 1986), the time to change employment will also increase. Therefore, adjustment costs are possibly asymmetric and lead to different adjustment processes when employment increases or decreases (cf. Hamermesh and Pfann, 1996). If these costs are very high, then the velocity of adjustment will probably slow to finish the process before the next wage shock occurs. Then, the observed employment levels will reflect short-run elasticities but not long-run elasticities. The estimated values are possibly misleading and therefore, asymmetrical.

Studies that investigate the short-run adjustment process use quadratic adjustment cost functions with unequal costs of hiring and firing employees and, therefore, estimate differences in the velocity of the adjustment process (e.g., Dhyne *et al.*, 2015; Ilut *et al.*, 2014; Yaman, 2011). Most of the studies detect some differences in the time to adjust to a new equilibrium, but it is not clear whether it is costlier to employ further workers or to dismiss them (Hunt, 2000). Azetsu and Fukushima (2009) indicate that firings costs in Japan are larger than the corresponding hiring costs. Furthermore, this relation is more important for manufacturing than for non-manufacturing. Similar evidence is presented for the

production sector in Italy (Jaramillo *et al.*, 1993). Other studies confirm this outcome for Germany (Jung, 2014; Kölling, 1998), France (Abowd and Kramarz, 2003; Goux *et al.*, 2001; Kramarz and Michaud, 2010), and Norway (Nilsen *et al.*, 2007). On the other side, Pfann and Verspagen (1989) for the Netherlands and Hamermesh (1993, 2008) as well as Hamermesh and Pfann (1996) for the US indicate larger hiring than firing costs. Pfann and Palm (1993) show higher dismissal costs for non-production workers, whereas they find higher hiring costs for production workers in the Netherlands and Great Britain.

However, even if many investigations use quadratic adjustment cost functions, the economic literature shows that other assumptions about the structure of adjustment costs are not rejected (cf. Hamermesh, 1989; Yaman, 2011). Lumpy or linear cost functions with an immediate adjustment to the new equilibrium level, illustrate results with at least the same efficiency, especially when most cases show only a few workers were hired or fired (King and Thomas, 2006). In addition, several studies with quadratic costs show that most of the adjustment processes take place within a short time period, usually less than year. Therefore, to estimate adjustment-appropriate processes, quarterly or monthly data are needed, and annual data, like the data used here, would be overaggregated (Hamermesh, 1993, 253).

In addition, the adjustment process is not constant. Upward *et al.* (2014) find that the pattern to employ or dismissal workers is similar to the US (Davis *et al.*, 2012) but different to the behavior in France (Abowd *et al.*, 1999). Although the rates of hirings and separations are smaller than in US establishments, Abowd *et al.* (1999) find that the adjustment processes in the US and France are mainly driven by younger employees with low experience, low skilled workers, employees with lower wages, part-time or temporary contracts. Gartner and Klinger (2010) and Herzog-Stein and Seifert (2010) show in their work that recent economic upswings in Germany have a bigger impact on the increase in employment than 20 years ago, whereas the opposite effect occurs for recessions.

Moreover, the average time to fill a vacancy in Germany was less than 3 months in 2015, and the time of unexpected vacancies was less than a month. A successful hiring for highly skilled workers takes less than 4 months on average with 4 weeks of unexpected vacancies (Brenzel *et al.*, 2016). This supports the assumption that yearly data are overaggregated and the estimation of the time to adjust is upwardly inflated (cf. Jung, 2014). From the discussion, we therefore conclude that dynamic adjustment processes do not interfere with the results presented below, as they are usually completed within a year and the data do not allow estimating shorter periods.

Rationing of (skilled) labor is another possible source for asymmetrical wage elasticities. In some cases the firms overestimate the importance of their current decisions compared with actions in the future (cf. Kahneman and Tversky, 1979). Myopic behavior neglects the costs of hiring employees in the future, when executives have to decide about actual dismissals. Then, the elasticities could become asymmetrical even if a rationing of (skilled) labor or labor hoarding is detected. Skill shortages in the short run often appear through the business cycle and increase when the economy grows with a larger number of vacancies respective to lower unemployment (Elsby *et al.*, 2010). From the German perspective, one can identify three types of reasons for labor shortages that are described in the existing literature. First, demographic changes toward a decline in population, late entrance on the labor market, and early retirement that reduces labor supply. Second, skill biased technological changes that increase the demand for skilled workers, and third, insufficient schooling responsible for deficiencies in the quality of human capital. These reasons could determine the long-run macroeconomic development of skill shortages (Bellmann and

Hübler, 2014). This resulted in a higher probability of skill shortages, especially if there is low mobility and other sources of mismatch preventing the hiring of new personnel (Ghayad and Dickens, 2012). The restriction of labor demand due to a lack of skilled labor is controversially discussed in Europe, especially in Germany since the early years of this millennium (cf. Bellmann and Hübler, 2014). Although it is not clear if a common shortage of skilled labor exists, many firms have reported that they cannot hire as many workers as they want. These reasons are not only specific for Germany but are also discussed in an European context (Dunkel, 2011). There is also a predicted shortage of skilled workers in future for the US dealing with the retirement of the baby boomer cohort. However, until now there is no empirical evidence of skill shortages (Cappelli, 2015). The panel data used in the subsequent analysis, the IAB Establishment Panel, also survey whether firms feel restricted in the hiring process. Table 1 contains the outcome of this question for the period from 2004 to 2014:

As expected, Table 1 indicates that reported labor shortages depend on economic development, as the share of firms decreased during the Great Recession of 2008. Nevertheless, the problem establishments faced seems to increase in the surveyed period from a share of about 10 per cent to almost a quarter of all establishments with at least 20 employees. If the firms are rationed in their labor demand, then hiring becomes more difficult compared with layoffs. Then, the own-wage elasticities for increasing employment should be smaller in absolute terms compared with the values of the decreasing number of workers, as the reaction to a reduction in wages is forced to be lower than desired. This may also be the case if firms anticipate shifts in the need for new skills in the future. If the firms recognize an existing labor shortage, then rational agents would take into account the increased hiring efforts when they decide to lay off employees, which would result in larger labor hoarding activities during a business cycle (Oi, 1962). When Okun (1962) analyzed the procyclical behavior of labor productivity, he introduced the modern notion of labor hoarding. Several empirical studies confirmed the assumption of labor hoarding of the business cycle (e.g., Fair, 1985; Fay and Medoff, 1985; Hall *et al.*, 1986). Although, labor hoarding reduces the dynamics of adjustment, it does not change the long-run equilibrium labor demand and, therefore, the long-run elasticities (Hamermesh, 1993). In addition, the idea behind labor hoarding is that it is costly to fire employees in recession because one has also to take into account hiring costs when the job is filled again in the next upswing

Table 1. Share of firms reporting restricted labor demand

Year	Obs.	Share of Establishments (S. Dev.)
2004	7.596	0.104 (0.305)
2005	7.560	0.101 (0.301)
2006	7.490	0.139 (0.346)
2007	7.554	0.178 (0.383)
2008	7.649	0.201 (0.401)
2009	7.782	0.137 (0.344)
2010	7.380	0.181 (0.385)
2011	7.270	0.237 (0.425)
2012	7.675	0.236 (0.425)
2013	7.705	0.211 (0.408)
2014	7.599	0.246 (0.431)

Source: IAB Establishment Panel 2004–2014.

and vice versa. As one takes into account both, hiring and firing costs, when the number of employees is increased or decreased, it is likely that the adjustment processes due to labor hoarding are rather symmetrical.

Bounded rationality could be another reason for asymmetrical labor demand elasticities. Some authors consider the hypotheses of entrepreneurs as profit-maximizing rational agents with steady preferences and as being visionary as unrealistic (Cartwright, 2014). For example, people also follow economic narratives, which help to reduce complex problems and therefore support decision-making by framing the individual view on actual occurrences (Shiller, 2017). Decisions are, then, not necessarily rational in the sense that considerable information is processed independently from the individual point of view. In the following, we will focus on two models that try to explain decisions under risk without the assumption of strict rationality.

Concepts of behavioral economics are not often used in labor economics, especially in labor demand. Only a limited amount of work in labor economics has analyzed so-called nonstandard decision-making (DellaVigna, 2009; Dohmen, 2014). If psychological aspects are considered, they are applied to study individual schooling and training choices, savings and retirement decisions or job search behavior. Nevertheless, behavioral economists often analyze the decision-making within firms. Especially, Behavioral Finance deals with corporate decision-making of executives (Barber and Odean, 2007; Daniel *et al.*, 2001; De Bondt, 1993; De Bondt *et al.*, 2008). Preferences of executives constitute another element of decision-making in behavioral economics.

One usual assumption about rationality in economics is risk aversion. This means people accept a smaller but safer outcome instead of a higher expected result that carries uncertainty. In addition, they will act according to this rule when they expect either losses or gains. Since Kahneman and Tversky (1979) introduced their prospect theory, showing systematic deviations from the assumptions of utility theory, researchers identify several preference frameworks. The most important features are loss aversion, mental accounting, and self-control (e.g., Haigh and List, 2005; Henderson and Peterson, 1992; Shefrin and Statman, 1985; Shefrin and Thaler, 1988; Tversky and Kahneman, 1992). If the people are aware of losses instead of risks, they are willing to take high risks to avoid large forfeitures. If this result is valid, then the decision makers' preferences alter depending on the state of their situation. In addition, this could be applied to labor demand at the establishment level. If wages decrease, production costs will fall and expected gains will increase. Then, firms will probably expect larger but uncertain gains and they should accept a safe but lower outcome compared with the expected value. In the sense of labor demand, a safe situation could be to employ only a few additional workers to avoid problems with hidden characteristics and possible large costs of dismissals in the future. In the opposite situation, if wages increase, then profits are likely to decrease. If the assumption of loss aversion is applied to this situation, the decision makers become prepared to take higher risks to avoid high losses. In such a situation, layoffs have the chance to decrease losses, as this reduces production costs, and the marginal productivity of workers increases. This is more risky, however, as the firms are unsure about future hiring when the economic situation becomes better. The costs of searching for new personnel and the hidden characteristics of the new workforce are possibly unknown at that moment. Then, loss aversion affects the size of labor demand elasticities. When firms are less willing to hire when wages decrease and more willing to lay off workers when wages increase, one should observe larger long-run negative elasticities when employment falls and smaller negative long-run elasticities when employment grows.

Another hypothesis about human behavior is the endowment effect (Thaler, 1980). Here, the focus is on the value of goods. The owner seems to give a higher value to that particular good compared with a person who does not own that item. Therefore, it is possible that the price at which a person is willing to buy a good ('willingness to pay') is different from the price at which a person is willing to sell the same good ('willingness to accept'). Although the employees are not 'owned' by the entrepreneur, one could assume that labor is crucial for firms to produce goods or services. Therefore, if one tries to adopt the hypothesis of endowment effects to firm behavior, taking into account the qualification of the workers, employed labor possibly is of a higher value to the firms when compared with labor that is not employed in the company. This means that a kind of 'willingness to hire' is larger than a kind of 'willingness to fire' if wages increase or decrease, possibly because of firm-specific human capital and a smaller amount of hidden characteristics in addition to behavioral explanations. Moreover, because of varying relative prices among the different types of labor, asymmetrical cross-wage elasticities occur in this case. From the arguments, it is obvious that loss aversion and endowment effects possibly have opposite effects for own-wage elasticities, whereas the latter is also indicated by asymmetrical cross-wage elasticities, e.g., it should be easier to substitute less-skilled workers with employees on a higher qualification level, just as in the opposite case.

Current literature on labor demand on the firm level does not often consider the effects described above. Bellmann and Hübler (2014) analyzed skill shortages in Germany during the time of the Great Recession. They found that skill shortages are affected by the economic cycle, but the outcomes are more or less short-term effects. Most of the firms overcome these problems over a longer period. Successful strategies to fill vacancies are long-run personnel staff development, employing apprentices, and training for the firms' workforce.

Moreover, although many models of behavioral economics are applied to labor economics, almost none of them deal with labor demand at the microeconomic level (cf. Berg, 2015; Dohmen, 2014; Wang, 2016). Usually, investigations about labor demand elasticities rely on the assumptions of the neoclassical standard model (cf. Addison *et al.*, 2014). An overview of the various existing studies that are based on translog cost functions or other empirical types of cost or production functions like CES, Cobb–Douglas, or generalized Leontief functions is given in Hamermesh (1993) and Lichter *et al.* (2015). Even though it is not always confirmed by empirical research, it is normally assumed that low-skilled workers show larger (i.e., more negative) own-wage elasticities compared with other skills probably because of the peripheral or marginal employment of low skilled (Addison *et al.*, 2008; Summers, 1996).

The studies that deal with asymmetries mostly analyze dynamic adjustment models and estimate differences in the velocity of the adjustment process (e.g., Azetsu and Fukushima, 2009; Dhyne *et al.*, 2015; Ilut *et al.*, 2014). It is important to stress the point that the goal of the work here is to look at the size of the long-run elasticities and not at the velocity of employment changes. However, we will not investigate dynamic adjustment processes in the subsequent analysis, as previous research show that the data used is probably overaggregated and adjustment to a new amount of employment is usually completed within a year (cf. Hamermesh, 1993, 253). In the following section, we introduce the empirical model of fractional panel probit regressions and the data used in this analysis.

3. Empirical model and data

The empirical model used in the study at hand is based on labor demand equations and is derived from a translog cost function (Berndt and Khaled, 1979). Initially, the following form is assumed:

$$C = C(w_i, r, Y), \quad [1]$$

where C is the cost, r is the interest rate, w_i is the wages for different qualifications, and Y is the firm's output. As such, the translog cost function derived from equation (1) is given by (Hamermesh, 1993, 40):

$$\ln C = \ln Y + a_0 + \sum_i a_i \ln w_i + b \ln r + 0.5 \sum_i \sum_j c_{ij} \ln w_i \ln w_j + 0.5 \sum_i d_i \ln w_i \ln r, \quad [2]$$

where a_0 , a_i , b , c_{ij} , and d_i are parameters and $\ln C$, $\ln Y$, $\ln w$, and $\ln r$ are the logarithms of C , Y , w , and r , respectively. In addition, the following conditions should hold (Hamermesh, 1993, 40):

$$\sum_i a_i + b = 1 \quad [3]$$

$$\sum_i \sum_j c_{ij} + \sum_i d_i = 0 \quad [4]$$

$$c_{ij} = c_{ji} \quad [5]$$

Equations (3) and (4) stem from the underlying assumption of translog cost functions that C is homogenous of degree 1 in w_i and r , and equation (5) reflects the requirement on the cost function, that the function is twice the differential and the second cross derivatives are symmetric. Applying Shephard's lemma to labor input and taking the ratio to labor costs into account yields:

$$s_i = a_i + c_{ii} \ln w_i + \sum_j c_{ij} \ln w_j + d_i \ln r, \quad [6]$$

where s_i is the share of labor costs for each skill level in total revenue ($w_i L_i / Y_i$). Therefore, we estimate a system of three different share equations, as we observe the same number of different qualifications. Moreover, we use the production function in its heterothetic form. This is a more general case than a linear homogenous production function, in which output is related to factor prices and depends on the scale of the output Y . This is normally the case when there are several existing technologies to produce identical goods. Significant estimations of the additional parameter Y would support the assumption of heterotheticity.

The dependent variable of equation 3 is the wage share of total costs of the firm (cf. Hamermesh, 1993). The values of the share bounded between 0 and 1. Therefore, it is not possible to apply a linear regression model like OLS or, if unobserved heterogeneity is detected, linear Fixed or Random Effects estimation. The economic literature mainly offers two different approaches to overcome the problems of a share variable (Wooldridge,

2010a). First, a logs odds transformation of the dependent variable. Then, s_i is divided by $(1-s_i)$ to create the odds of the variable. Afterwards, the logarithm of the odds is used as a dependent variable in a linear regression. Second, Wooldridge (2010a) proposed a fractional panel probit estimation, where the non-linear nature of the variable is used within a probit model. The fractional panel probit estimation has some advantages over the logs odds transformation of the dependent variable. Even though it is then possible to estimate a rather simple regression model, two severe problems can occur when this procedure is used. First, shares of zero and one are not defined when a log odds transformation is conducted. Second, a linear functional form does not reflect the possible important non-linearities. Especially, the former of both arguments is important here, as the wage shares are calculated for each skill level and we observe a number of firms in the data that do not employ all kinds of workers. Then, the particular wage share is zero and the log odds transformation creates a missing value. This could be a source of a selection bias if there are specific reasons of employing some kind of workers or not. Using a fractional panel probit model makes it possible to include these observations in the analysis. Therefore, we prefer to estimate this model instead of using a log odds transformation of the dependent variable.

The model is based on the fractional nature of the wage share. Assuming a normal distribution of the dependent share s (e.g., a probit model), Papke and Wooldridge (2008) and Wooldridge (2010b) proposed the following model:

$$E(s_{it}|X_{it}, c_i) = \Phi(X_{it}\beta_i + c_i), \quad [7]$$

where s_{it} is the share variable from equation 6, $0 \leq s_{it} \leq 1$; $t = 1, \dots, T$, X_{it} are the covariates of the model like $\ln w_i$, $\ln w_j$, and other variables discussed in the subsequent data section. β_i are the parameters, c_i are the firm-specific heterogeneities, and Φ is the standard normal cumulative distribution function (cdf). From equation 5, the partial effects not only depend on the estimated β s but also on the density function ϕ :

$$\frac{\partial(s_{it}|X_{it}, c_i)}{\partial X_{it}} = \beta_i \phi(X_{it}\beta_i + c_i) \quad [8]$$

As the cdf is a monotonic function, the value of β identifies the direction of the partial effect. Unfortunately, because of the unobserved nature of c_i , it is not possible to calculate the partial effects from equation (8). One possibility applied to calculate the partial effects in this model is to average the individual partial effects and model the distribution of c_i , given strictly exogenous covariates X_i , so that the selection becomes ignorable (Papke and Wooldridge, 2008; Wooldridge, 2010b). Applying assumptions to the random nature and distribution of c_i , Wooldridge (2010a,b) identified the average structural function (ASF) of the model, which allows for consistent estimation of the expected value of equation 5:

$$ASF(X_i) = N^{-1} \sum_{i=1}^N \Phi \left(\frac{X_i t \hat{\beta}_i + \sum_{r=2}^T (\hat{\psi}_r + \bar{X}_i \hat{\xi}_r)}{\exp(\sum_{r=2}^{T-1} \hat{\omega}_r)} \right), \quad [9]$$

where r is the number of observations of an establishment in the panel, \bar{x}_i is the average of X_i over time, ψ and ξ are the parameters of the model that identifies c_i , ω_r indicates the deviation of each subgroup from the variance in each establishment, and \wedge define the

estimated values. The average partial effects (APE) are then given by the derivative of equation (9) with respect to X_i :

$$APE(X_i) = \hat{\beta}_i N^{-1} \sum_{i=1}^N \varphi \left(\frac{X_i t \hat{\beta}_i + \sum_{r=2}^T (\hat{\psi}_r + \bar{X}_i \hat{\zeta}_r)}{\exp(\sum_{r=2}^{T-1} \hat{\omega}_r)} \right) \quad [10]$$

In the current paper, the focus is not on the calculation of the APEs, but on the determination of own- and cross-wage elasticities. Therefore, the average elasticities are derived from the APEs by using the ASF as the expected means of the cdf. The average elasticities η for the estimated parameters are then given as follows (cf. Kölling, 2012):

$$\eta_{L_i w_i} = \frac{APE(\ln w_i)}{ASF(X_i)} - 1 \quad (\text{own} - \text{wage elasticities}), \quad [11]$$

$$\eta_{L_i w_j} = \frac{APE(\ln w_j)}{ASF(X_i)} \quad (\text{cross} - \text{wage elasticities}), \quad [12]$$

with L_i as the number of workers of skill level i .

German establishment data from the IAB Establishment Panel are now used to estimate the fractional panel probit model of labor demand. The IAB Establishment Panel is a representative employer survey of employment parameters at individual establishments. Nearly 16,000 establishments from all branches of the economy and of all sizes are surveyed annually and nationwide from the end of June until October. The survey is carried out orally by way of personal interviews conducted on behalf of the Institute for Employment Research (IAB) of the German Federal Employment Agency. This representative survey of establishments covers a wide range of questions on a great many topics related to employment policy that are examined in various research projects. The standard annual program of questions is complemented by topics of current interest. The IAB Establishment Panel has been in existence in western Germany since 1993 and in the east since 1996. As a comprehensive longitudinal dataset, it forms the basis for research into the demand side of the labor market. The data provided by establishments are intended to help the placement and advisory services of the Federal Employment Agency orientate their activities more closely to the realities experienced within the establishments themselves (Fischer *et al.*, 2008, 2009).

The data are a stratified random sample of all German establishments with at least one employee covered by social insurance contributions. In particular, the survey uses 17 industries, 10 employment size classes, and 16 regions (the Bundesländer) as particular strata of the total population (Fischer *et al.*, 2008, 2009). The IAB Establishment Panel shows a very high response rate of over 70 per cent to 80 per cent for establishments that have participated more than once. Table A4 in the Appendix shows the influence of panel attrition on the observations. The data are unbalanced, however, as new establishments replace panel mortality through exits and non-response. In the work at hand, the data are restricted to the period from 2004 to 2014, i.e., 11 time periods, as the variable that indicates labor shortage respectively skill shortage has been collected since then. In total, observations of more than 85.000 establishments are available for the subsequent analysis. (Fischer *et al.*, 2008, 2009).

Additional data stem from the Establishment Historical Panel, which provides detailed information from official labor statistics about the particular qualifications of the workers in the observed establishments and their respective daily remuneration (Eberle and Schmucker, 2017). In detail, the Establishment Historical Panel contains the number of low-, medium-, and high-skilled employees with full- or part-time contracts. Low-skilled employees are defined as individuals with a lower secondary, intermediate secondary, or upper secondary school completion certificate but no vocational qualifications. Medium-skilled employees are individuals with a lower secondary, intermediate secondary, or upper secondary school completion certificate and a vocational qualification. Please note that the difference between low- and medium-skilled workers is not about school completion, but about vocational qualification. This indicates the high influence of the domestic vocational training system on the labor market in Germany. The group of high-skilled employees of an establishment are those who have a degree from a university (including universities of applied sciences '*Fachhochschule*'). In order to calculate the number of employees for the respective qualifications, part-time workers are assigned with the value of 0.5. As wage shares are defined as the proportion of labor costs in total revenue ($w_i L_i / Y_i$), we also use average remuneration of the particular skills and the firms' turnover, Y , to calculate s_i for each skill level as the dependent variable. Therefore, we end up with regressions for three different wage shares that are estimated simultaneously with a seemingly unrelated regression approach. Moreover, the regressions exclude establishments with less than 20 employees in total to ensure a higher variability of the dependent variables.

Also, the official data offer additional information about the mean and the median daily remuneration of full-time employees for each particular skill group. The variable includes special payments, such as holiday pay or 13th monthly salary, but only contains values up to the upper earnings limit for statutory pension insurance contributions. This means that about 10 per cent of the data is censored and the earnings means are biased. To remedy this censoring problem, the data provider regularly imputed the information on daily wages according to the procedure of Card *et al.* (2015) before the values were calculated. For this analysis, the median of wages is used, as it is less affected by coincidental inferences and censoring. In addition, we control for the influence of very small and large wage on the results. As the results do not change significantly, we will refer to the results from the complete data. The results of the regressions without probable outliers are available from the author. Furthermore, from equation 3, the logarithms of daily wages are used in the regressions. The calculation of the elasticities in equations (11) and (12) are based on the parameter estimates of these covariates. To control whether there are differing elasticities for increasing or decreasing employment, additional dummy variables are created that become one if the establishment experienced a growing workforce for each qualification level. Out of this, we calculate interaction variables with the wage variables, indicating possible differences in the parameter estimates for increasing or decreasing employment. As we analyze establishment-specific changes in employment, we assume that responses to wage changes are in general asymmetric. The interaction variables should indicate these asymmetries, independently to sector-specific developments or economic cycle considerations.

Besides that, the used panel data are very large and based on a representative sample, the empirical work has some limitations that have to be mentioned if one wants to interpret the results. First, the data consist of establishments rather than companies. This is the same for small companies with only one establishment. Therefore, we have to assume that the behavior on the establishment level is a good instrument for the behavior of the whole

company. In addition, establishments that report changes in the company structure, like the inclusion or exclusion of parts of the company were excluded from the sample. Also, the entity was dropped from the sample, if major structural changes were surveyed. Moreover, the distinction of the workforce into three different skill levels is rather loose, i.e., it is not possible to observe peripheral low-skilled or high-skilled executives directly. Finally, the remuneration data consist of daily wages and the only information about the working hours is if the employee works full- or part-time.

According to the theoretical considerations, the estimations should take care of the probable influence of labor shortage or skill shortage on the estimated labor demand elasticities. To identify the specific influence of labor shortage in the regressions, we introduce some regressors that show whether an establishment has experience with labor shortage or not. From the information in IAB Establishment Panel, it is possible to create a dummy variable indicating labor shortage. This is used as a further covariate. Although the information about labor shortage stems from the establishments' answers in the survey and is not verified by common data, we assume that this variable is an indicator for restrictions in labor demand. Nevertheless, one has to keep in mind that the establishments' experience with skill shortage is probably related to hirings and increasing employment. But, as the sample is restricted to firms with at least 20 employees, it is not unlikely that the establishments regularly have to hire employees independently whether their employment increases or not. Therefore, we assume that the variable contains reliable information. Negative estimates of the variable would indicate restrictions in labor demand for these skills or a complementary relationship with restricted inputs. A positive outcome is probably a sign of a substitutional relationship among skills as the observed skill level exhibits a larger demand for labor. Moreover, we used interaction variables of the particular dummy and the wage variables to control for the influence of labor shortage on the estimated own- and cross-wage elasticities. If labor shortage influences labor demand, we would see different effects. At first, the dummy should be negative for that type of labor that is affected by labor shortages. This is probably the case for skilled labor as there is some public discussion about a lack of qualified labor. If the firms use other types of labor instead, then we should observe a positive parameter for the dummy variable. In addition, the interaction variable indicates the influence of labor shortage on the elasticities of labor demand. If a lack of skilled labor appears, the number of hirings of this kind of worker is probably lower than wanted and, therefore, the elasticity for growing firms is probably lower than without skill shortages. In addition, the employers should take care of their skilled employees, if there is a lack of skills. If they like to avoid voluntary dismissals of these workers, then the magnitude of downward adjustments according to a wage shock should be lower, too.

The model derived previously is very useful for an empirical analysis, but has to be expanded with additional variables to overcome oversimplifying aspects. Therefore, characteristics of the workforce were included in the analysis along with structural parameters (Groschen, 1991). We used the shares of part-time workers, female workers, temporary employees, and employees subject to the social insurance scheme to control for the employment structure in the firms. As we assumed a heterothetic cost function, the regressions should contain some information about the production level. The IAB Establishment Panel contains information about firms' value added where intermediate materials were excluded from turnover in the year prior to the interview. Because we used this variable in our investigation, establishments that did not report turnover, including banks, insurance

companies, and public administrations, were excluded from the database. From equation 3, the logarithm of value added is used.

Other variables used were the logarithms of the Euribor interest rates, and dummies for Eastern Germany; for coverage by a collective agreement; the firms' profitability; the state of machinery; firm size; industries; and years. As the model is defined for two input factors, labor and capital, we need some information about capital costs. Market conditions are regularly expressed using interbank rates like the Euribor. At this rate banks offer to lend unsecured funds to other banks. It is daily published for different time periods and used as a reference rate in the euro wholesale money market based on the averaged interest rates. Firm-specific indicators that influence credit worthiness are, e.g., firm size, profitability, state of technical equipment and industry. The Euribor interest rates were used as an instrument for capital costs, allowing capital to be variable over time. Profitability and state of technical equipment base on a self-rating of the establishments on a range from 1 (low profitability respectively outdated technical equipment) to 3 (high profitability respectively up-to-date equipment). Information about 41 different industries is used to create respective dummies. In addition, the model uses time dummies for each wave of the panel. Moreover, the nominal values of these variables were discounted by the producer price index. Table A1 in the Appendix contains the descriptive statistics of the main variable used in this investigation.

The labor demand model used here is a static model and does not contain lagged variables, as a dynamic model does, to calculate the adjustment processes. As discussed in Section 2, most of the adjustment process takes place within a year, and annual data are overaggregated; additionally, the use of lagged dependent variables to model labor demand dynamics is caused by a quadratic adjustment of the cost function. This is very restrictive, and questionable, as empirical studies with other cost functions, like lumpy or linear costs, illustrate results with at least the same efficiency (Hamermesh, 1993).

The question of whether price and output were exogenous depends on the assumption that the labor supply is infinitely elastic (i.e., firms take wages as exogenously given and are able to hire as many employees as they demand to maximize profits). Assuming that the model is specified correctly, studies with microdata generally should not have problems with the endogeneity of the mentioned variables (Freier and Steiner, 2010; Hamermesh, 1993, 68). In the context of the German labor market in the observed period with imperfect competition, rigid wages and high unemployment rates during the observation period still indicate substantial excess of labor supply despite improvement in the situation on the labor market in recent years. However, one has to keep in mind that, at least for the highly skilled employees, the German labor market situation has changed over the last few years. In addition, as mentioned in the theoretical considerations, restriction of labor demand is one possible source for asymmetries of wage elasticities. Therefore, next to the inclusion of a variable about labor shortage, we apply a two-step control function to control for endogeneity (Wooldridge, 2015). On the first step, we estimated wage regressions for each skill level using all other covariates of the empirical model and additional regressors to fit the identification criteria. Also, we account for unobserved firm heterogeneity. Using the outcome of the regressions, the error is calculated for each equation. On the second step, these three error terms are used as further covariates of the empirical model in equation 5. In all cases, these error terms stay insignificant in the regressions, indicating that endogeneity of the wages could be neglected in the subsequent analysis. The outcome of the wage regressions and the model with the error terms is presented in the supplement. After this deeper look at the data, the next section presents the outcome of the fractional pane probit regressions.

4. Results of the empirical analysis

This section contains the results of estimations of the empirical model in equation 3. We used three dependent variables indicating the wage share of different kinds of labor. Each equation was estimated as a fractional panel probit model. We applied a system of seemingly unrelated regressions (SUR) to estimate the outcome of all equations simultaneously. Subsequently, we present the complete model with all interaction variables to detect differences in the labor demand elasticities. The results of a SUR without interaction variables are shown in the Appendix. Table 2 contains the parameter estimates of the complete model:

All parameters for own wages are statistically significant and show the expected size between zero and one. As the values are close to zero, the calculated elasticities will be near to minus one (see Table 3). The only significant cross-wage parameter is the

Table 2. Seemingly unrelated estimations of labor demand with a fractional panel probit model

	(a) Low skilled	(b) Medium skilled	(c) High skilled
Log. of wages for low skilled per capita	0.052** (0.008)	−0.001 (0.007)	0.004 (0.007)
Log. of wages for medium skilled per capita	0.021 (0.028)	0.071* (0.028)	0.072** (0.026)
Log. of wages for high skilled per capita	0.007 (0.009)	0.012 (0.008)	0.053** (0.011)
Interaction variables: Dummy for larger employment of particular skill level•			
Log. of wages for low skilled per capita	0.036** (0.009)	−0.001 (0.005)	0.001 (0.008)
Log. of wages for medium skilled per capita	−0.011 (0.011)	0.013 (0.007)	−0.018 (0.012)
Log. of wages for high skilled per capita	−0.014 (0.007)	−0.008* (0.004)	0.025** (0.009)
Interaction variables: Dummy for reported rationing in labor demand•			
Log. of wages for low skilled per capita	−0.005 (0.011)	0.004 (0.008)	0.025** (0.007)
Log. of wages for medium skilled per capita	−0.002 (0.016)	−0.026** (0.010)	−0.015 (0.015)
Log. of wages for high skilled per capita	−0.031** (0.010)	−0.006 (0.006)	−0.001 (0.011)
Dummy for reported labor shortage	0.175** (0.048)	0.129** (0.048)	−0.032 (0.073)
Log. average 12-month Euribor	0.013 (0.019)	−0.003 (0.008)	−0.019 (0.022)
Log. of value added	−0.043** (0.008)	−0.043** (0.007)	−0.056** (0.010)
Share of part-time workers	0.019 (0.016)	0.009 (0.018)	0.007 (0.025)
Share of temp. Employed	0.006 (0.017)	−0.004 (0.009)	−0.012 (0.017)
Share of employed persons subjected to the social insurance scheme	0.037 (0.027)	0.030 (0.022)	0.070 (0.041)
Share of female workers	−0.009 (0.024)	0.016 (0.021)	−0.001 (0.028)
Coverage by a collective agreement	0.004 (0.005)	0.002 (0.004)	−0.003 (0.006)
Dummy for Eastern Germany	0.123** (0.009)	0.004 (0.005)	−0.081** (0.009)
Log Pseudolikelihood	−14.842	−93.735	−25.370
Wald Test χ^2 (df.)	9,999** (261)	9,582** (261)	9,654** (261)
Obs. (Establ.)	19,687 (6,412)	19,687 (6,412)	19,687 (6,412)

Source: IAB Establishment Panel 2004–2014.

Notes: The model also includes the following dichotomous and auxiliary variables: establishment size (7 dummies), firm profitability (2), state of technical equipment (2), industry (40), year (10), the means of the time variant covariates, and a constant. Robust standard errors adjusted for clustering on establishments in parentheses. ** and * denote significance at the .01 and .05 levels, respectively.

remuneration of medium-skilled workers in the demand for high-skilled employees. The wages for high-skilled workers do not affect the labor demand for medium-skilled workers on a statistically relevant level, and the difference between both parameters is significant on a 5 per cent level. This could support the assumption of a kind of endowment effect discussed in Section 2, as higher wages for medium-skilled workers increase labor demand for high-skilled workers, but not the other way around. But one has to keep in mind that this could also be the result of changes in skill demand due to technical progress and information asymmetries in hiring.

The estimations of the interaction variables for firms with growing employment of respective skill levels for own wages are positive and statistically significant for low- and high-skilled workers. The outcome for medium-skilled workers is also positive, but it is only significant on a rather weak 10 per cent level. According to the calculation in equation (11), this indicates less negative labor demand elasticities for firms with increasing employment of the observed skill level. Independently of the time that it takes to adjust employment, this means that a 10 per cent increase or decrease in specific wages leads to different corresponding changes in employment. A downward adjustment is always larger than an upward adjustment of employment for a wage shock of the same size in absolute terms. This is in line with the model of loss aversion presented in Section 2, and probably supports the proposal of bounded rationality in labor demand, as we controlled for other sources of asymmetry.

In addition, Table 2 shows some estimates for the indicator of labor shortage and its interaction with the wage variables. The parameters for the dummy variable specifying reported labor shortage of the surveyed firms are significantly positive for low- and medium-skilled employees, whereas the outcome for high-skilled workers is, as expected, negative but statistically insignificant. The corresponding elasticities point to a 12.2 per cent and 9.4 per cent increase in employment for low- and medium-skilled workers in firms that have problems with hiring of new personnel. In combination with the negative sign of the parameter for high-skilled workers, this could be a sign of substituting unfilled vacancies for highly skilled workers with employees on a lower qualification level. There are also some statistically significant parameter estimates for the interaction variable between reported labor shortage and wage levels for particular skills. The outcome presents additional asymmetries, as the relationships between high- and low-skilled labor becomes more complementary in the equation for low-skilled labor and more substitutional in the

Table 3. Calculated average partial elasticities of estimates from Table 2

	(a) Low skilled	(b) Med. skilled	(c) High skilled
<i>Constant and decreasing employment of particular skill level</i>			
Log. of wages for low skilled per capita	−0.964**	−0.001	0.003
Log. of wages for medium skilled per capita	0.015	−0.948*	0.051**
Log. of wages for high skilled per capita	0.005	0.009	−0.963**
<i>Increasing employment of particular skill level</i>			
Log. of wages for low skilled per capita	−0.939**	−0.001	0.004
Log. of wages for medium skilled per capita	0.007	−0.939**	0.038*
Log. of wages for high skilled per capita	−0.005	0.003	−0.945**
Dummy for reported labor shortage	0.122**	0.094**	−0.023

Source: IAB Establishment Panel 2004–2014. ** and * denote significance of the underlying parameter estimates at the .01 and .05 levels, respectively.

demand for high-skilled labor. However, the influence on labor demand is rather low, and the particular total elasticities for firms with reported labor shortages stays insignificant. In addition, the expected muting effect of skill shortages on the demand for high-skilled labor is insignificant, whereas the elasticity of the demand for medium-skilled labor becomes more negative. This could be in line with the larger employment of this qualification level according to a substitution of vacancies for highly skilled workers. Additional regressions that differ between labor shortages in firms with growing or decreasing employment show no further insights. The particular covariates stay insignificant, indicating that restrictions on the labor market not only affect the recruitment on new workers but also the number of dismissals in the entity. Table 3 contains the corresponding elasticities for the estimated wage parameters.

The calculated own-wage elasticities are close to minus one but still in the expected interval (cf. Lichter *et al.*, 2015). As we control for the muting effects of a labor shortage, the outcome is not unlikely. In addition, there are only marginal differences between the different skill levels, indicating that a 10 per cent increase in remuneration leads to about a 9.5 per cent reduction in labor demand. The only significant cross-wage elasticity is the influence of wages of medium-skilled workers on the demand of high-skilled workers. The positive parameter supports a substitutional relationship with a drop of 0.5 per cent for highly skilled labor if the remuneration for medium-skilled labor increases by 10 per cent. The interaction variables for growing employment of the particular group and its wage level are always positive and at least significant on a 10 per cent level. Therefore, respective elasticities are less negative, showing a smaller reaction to shrinking wages than to a corresponding rise of the particular wages of the same absolute size. On average, the relative response to a 10 per cent fall of wages is about 0.1 and 0.25 per cent points lower than for a 10 per cent increase in wages. The differences are rather little but in line with the assumption of loss aversion behavior of the firms' executives. The only significant cross-wage interaction variable is the remuneration of highly skilled labor on the demand for medium-skilled labor. The negative parameter indicates a larger complementary structure of labor demand between medium- and high-skilled workers. This is the opposite effect of that in the demand for high-skilled workers and supports the assumption of an 'endowment effect' for the employment of highly skilled workers. Nevertheless, the parameter estimate is small and the calculated cross-wage elasticity for growing employment stays insignificant. From the empirical outcome, we can conclude that there are some asymmetries in labor demand for different skill levels, even controlling probable labor shortage. Hence, the results of the study are now summarized in the subsequent conclusion.

5. Summary

The study at hand discusses different reasons for asymmetries of firms' labor demand for the calculated elasticities. We identified three possible sources for these asymmetries: long-term adjustment processes that prevent labor demand from reaching an optimal level, labor shortage that reduces the number of wanted hirings, and behavioral explanations where the actions of the firms' executives are not independent from the establishment's actual situation. Especially, the effects of the so-called loss aversion and endowment effects are analyzed in detail.

To investigate whether there are asymmetrical labor demand elasticities and, in addition, to identify possible reasons for this behavior, we applied a fractional panel probit model

that takes into account unobserved heterogeneity. We used a large survey of German establishments over the period from 2004 to 2014 to estimate the model. As the data contain yearly observations and the available literature for Germany suggests that the average time to adjust to a new optimal labor demand is much faster, it is not possible to detect the effects of dynamic adjustment processes with the current survey. However, the data contain information about labor shortages at the establishment level, which is used to control for the effect of this involuntary lower employment. We argue that the remaining asymmetries are due to explanations from behavioral economics.

From the outcome of the regressions, we find support for both the influence of labor shortage and indications for loss aversion and the endowment effect. The employment of low- and medium-skilled workers is significantly larger in firms that report labor shortage, whereas the number of high-skilled workers is lower. Nevertheless, the latter estimate is not significantly different from zero. In addition, there are some statistically relevant parameters from the interaction variables between a dummy indicating labor shortage and the respective wage levels. Moreover, the results suggest that, controlling for labor shortage, calculated labor demand elasticities for all skill levels are more negative in firms that reduce employment of the particular qualification level. This probably supports the assumption of loss aversion in the behavior of firms' decision makers, as this outcome indicates that downward adjustment according to an increase in wages is larger than an upward adjustment according to a comparable fall in remuneration of the respective skill level. However, the differences in the levels are rather small but statistically significant, at least for low- and high-skilled workers. The results are robust when controlled for reported labor market restrictions and other important structural parameters that influence labor markets. The conclusion is that analyses of the labor market should allow for long-run asymmetrical behavior. It seems that additional aspects of behavioral economics are useful to finding more insights of firms' labor demand. However, although statistically significant, the estimated effects are quite small, and further research is needed to confirm the results of the study.

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Appendix

Supporting Information

Table A1. Descriptive statistics of the treatment variable

Variable	Obs.	Mean	St. Dev.	Min.	Max.
Total Employment	86,867	238.098	986.694	20	59,207
No. of low skilled	86,867	23.067	85.626	0	4406
No. of medium skilled	86,867	157.996	675.166	0	40070.5
No. of high skilled	86,867	38.686	221.906	0	16,969
Share of est. with increasing employment of low skilled	58,927	0.332	0.471	0	1
Share of est. with increasing employment of medium skilled	58,927	0.453	0.498	0	1
Share of est. with increasing employment of high skilled	58,927	0.392	0.488	0	1
Median daily remuneration of low skilled	58,155	73.274	28.088	.179	394.848
Median daily remuneration of medium skilled	86,385	83.157	26.740	.627	378.589
Median daily remuneration of high skilled	73,722	124.383	49.341	.844	586.187
Share of est. reporting labor shortage	83,260	0.179	0.383	0	1
Share of part-time workers	105,243	0.194	0.240	0	1
Share of temp. employed	105,765	0.071	0.151	0	1
Share of employed persons subjected to the social insurance scheme	106,477	0.829	0.272	0	1
Share of female workers	106,349	0.404	0.296	0	1
Coverage by a collective agreement	105,666	0.777	0.416	0	1
Log. average 12-month Euribor	106,478	0.791	0.654	−0.600	1.573
Log. of value added	61,900	14.566	2.140	3.792	22.709
Reported state of machinery (1=new)	105,148	2.155	0.686	1	3
Reported profitability (1=very profitable)	84,861	1.867	0.811	1	3
Dummy for Eastern Germany	106,478	0.633	0.482	0	1

Source: IAB Establishment Panel 2004–2014.

Table A2. Seemingly Unrelated Estimations of Labor Demand with a Fractional Panel Probit model

	(a) Low skilled	(b) Medium skilled	(c) High skilled
Log. of wages for low skilled per capita	0.123** (0.021)	−0.005 (0.014)	0.017 (0.012)
Log. of wages for medium skilled per capita	−0.026 (0.058)	0.153* (0.064)	0.159** (0.051)
Log. of wages for high skilled per capita	−0.014 (0.015)	0.010 (0.014)	0.097** (0.017)
Log. average 12-month Euribor	−0.034 (0.045)	−0.031 (0.024)	−0.017 (0.051)
Log. of value added	−0.090** (0.021)	−0.116** (0.022)	−0.128** (0.020)
Share of part-time workers	−0.006 (0.032)	−0.013 (0.038)	−0.034 (0.052)
Share of temp. Employed	0.036 (0.032)	0.025 (0.021)	0.007 (0.033)
Share of employed persons subjected to the social insurance scheme	0.004 (0.047)	0.029 (0.045)	0.132 (0.079)
Share of female workers	−0.037 (0.046)	0.007 (0.044)	0.038 (0.059)
Coverage by a collective agreement	0.009 (0.012)	0.008 (0.011)	−0.006 (0.014)
Dummy for reported labor shortage	0.011 (0.006)	0.005 (0.006)	0.005 (0.007)
Dummy for Eastern Germany	0.262** (0.034)	0.008 (0.014)	−0.180** (0.021)
Log Pseudolikelihood	−19.981	−123.9458	−33.981
Wald Test χ^2 (df.)	7,746** (269)	7,741** (269)	7,930** (269)
Obs. (Establ.)	25,534 (8,684)	25,534 (8,684)	25,534 (8,684)

Source: IAB Establishment Panel 2004–2014.

Note: The model also includes the following dichotomous and auxiliary variables: establishment size (7 dummies), firm profitability (2), state of technical equipment (2), industry (40), year (10), the means of the time variant covariates, and a constant. Robust standard errors adjusted for clustering on establishments in parentheses. ** and * denote significance at the .01 and .05 levels, respectively.

Table A3. Calculated Average Partial Elasticities of Estimates form Table A2

	(a) Low skilled	(b) Med. skilled	(c) High skilled
Log. of wages for low skilled per capita	−0.911**	−0.003	0.001
Log. of wages for medium skilled per capita	−0.019	−0.886*	0.111**
Log. of wages for high skilled per capita	−0.010	0.007	−0.932**

Source: IAB Establishment Panel 2004–2014. ** and * denote significance of the underlying parameter estimates at the .01 and .05 levels, respectively.

Table A4. Number of Observations for Each Establishment

Observations	Frequency	Per cent	Cumulated
1	10,282	6.34	6.34
2	10,110	6.24	12.58
3	9,645	5.95	18.53
4	8,784	5.42	23.95
5	9,050	5.58	29.53
6	18,744	11.56	41.10
7	9,667	5.96	47.06
8	9,568	5.90	52.96
9	8,883	5.48	58.44
10	10,720	6.61	65.06
11	12,881	7.95	73.00
12	17,568	10.84	83.84
13	7,865	4.85	88.69
14	18,326	11.31	100.00
Total	162,093	100.00	

Source: IAB Establishment Panel 2004–2014.

Additional Supporting Information may be found in the online version of this article at the publisher's web-site.

Table S1. Seemingly Unrelated Estimations of Labor Demand with a Fractional Panel Probit model (additional covariates indicating influence of labor shortage in growing firms).

Table S2. Fixed Effects Regressions of Log. of Wages (First Step of Control function).

Table S3. Seemingly Unrelated Estimations of Labor Demand with a Fractional Panel Probit model (additional covariates probable endogeneity of wage variables).

Table S4 Seemingly Unrelated Estimations of Labor Demand with a Fractional Panel Probit model (until 2007).

Table S5. Seemingly Unrelated Estimations of Labor Demand with a Fractional Panel Probit model (between 2008 and 2010).

Table S6. Seemingly Unrelated Estimations of Labor Demand with a Fractional Panel Probit model (since 2011).