Essays on Labor Adjustment and Real Exchange Rate Fluctuations

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Preface

This thesis consists of five chapters corresponding to a collection of five separate papers. Chapters 1-3 are based on joint work with Marc Blatter and Samuel Muehlemann, whereas Chapter 4 and 5 are own work.
With regard to contents, this thesis can be split into two parts. The first part (Chapters 1-3) consists of empirical studies about the characteristics and implications of hiring costs, i.e. the costs that a firm has to bear by recruiting new workers. The focus of the second part lies on real exchange rates. Chapter 4 analyzes the role of tradable and nontradable goods in explaining real exchange rate fluctuations and Chapter 5 tests for Purchasing Power Parity by applying nonlinear estimation techniques.

Introduction Part I

From a firm's perspective, hiring new workers is an expensive process. Hiring costs can basically be divided into two components: recruitment costs and adaption costs. Recruitment costs typically arise by posting a vacancy and processing interviews with considered applicants. Additionally, adaption costs occur once a newly employed worker has adapted to his new job and has reached his full productivity. As we will learn later on, these costs add up to a considerable sum. Knowing the structure of hiring costs concerns both microeconomists and macroeconomists. In microeconomic theory, hiring costs are an important part of modeling a firm's labor demand. From a macroeconomic perspective, it is important to know how firms adjust their employment over time, which in turn sheds light on the behavior of an economy's unemployment rate. The crucial importance of hiring costs across different fields of economics is reflected by a long and controversial discussion in the literature.

In chapter 1, we directly estimate the firm's costs of hiring skilled workers. Based on detailed Swiss establishment-level data, our findings provide strong evidence in favor of increasing marginal hiring costs. This implies that it becomes increasingly expensive for firms to hire a large number of skilled workers within a given time period.

Chapter 2 uses the rich data in order to make some proposition about the characteristics of the Swiss labor market. Recently, the theory of monopsonistic labor markets has become increasingly popular in the economic literature. In contrast to the data of the originator, the nature of our data allows us to estimate the parameters of the generalized model of monopsony, introduced by Manning (2006). In the framework of the generalized model of monopsony firms can increase their workforce both by offering a higher wage and by increasing their expenditures on hiring activities. Our empirical results are consistent with the predictions of this model. However, we point out that these results have to be interpreted with some caution, since the framework of the generalized model of monopsony is sensible to assumptions which could be inconsistent with data. In particular, we claim that there are two countervailing effects of a wage increase on labor costs. On the one hand, a higher wage reduces the separation rate, because less workers will leave the firm at a higher wage. On the other hand, a higher wage increases the firm's hiring costs, since wages are an important component of adaption costs.

Finally, the motivation of the analysis in chapter 3 is given exactly by the findings of chapter 1. Assuming that it becomes increasingly expensive for firms to hire skilled workers on the external labor market, we consider alternative ways of firms meeting the demand for labor and of avoiding excessive hiring costs. A common way is to offer training programs internally. After a young worker has completed his training, the firm can retain him as a skilled worker and thereby avoid the costs of hiring externally. For this reason, we analyze how hiring costs affect the firm's supply of training. Our empirical findings show that firms facing higher hiring costs provide more training opportunities than firms with lower hiring costs. In conclusion, it may be worthwhile for firms to train workers in order to reduce hiring costs, even if training itself is costly.

Chapter 1

The Costs of Hiring Skilled Workers[1]

1.1 Introduction

Firms deciding to hire new workers typically have to post a vacancy and then process interviews with the applicants they are interested in. Once a firm has decided to employ a new worker, it takes some time for the newly hired worker to adapt to his new job. In short, firms incur hiring costs, which include both recruitment and adaption costs. These costs amount to a considerable sum. On average, the costs incurred by Swiss firms for hiring and training a skilled worker are CHF 13,500, which equals about a quarter of an yearly wage payment. However, hiring costs can even add up to two years of a worker's salary.

The structure of hiring costs determines how the firms change their demand for labor over time. In an economy where firms do not face costs of hiring new workers, it is always optimal to recruit workers in order to keep employment at the desired level. However, since adjusting employment is costly, firms will often deviate from their desired level of employment, which would be chosen in an economy without frictions. Basically, the literature distinguishes between variable hiring costs and fixed hiring costs. Variable hiring costs depend on the number of recruits, whereas fixed hiring costs are independent of the number of hired workers. For example, search costs are a variable component of hiring

[1]This chapter is joint work with Marc Blatter and Samuel Muehlemann

costs. In contrast, the costs for maintaining a human resources department are independent of the number of newly hired workers and are therefore a fixed component of hiring costs.

With increasing marginal hiring costs, hiring a large number of workers at once is costly for the firm. This captures the idea that a large number of recruits may force firms to increase their search intensity. In addition, increasing hiring costs reflect the fact that firms have greater difficulties of finding appropriate matches between workers and jobs if they recruit a large number of workers at once. In the presence of increasing hiring costs, a firm adjusts its labor demand smoothly over time. By contrast if the firm faces fixed hiring costs, there is no reason for the firm to adjust slowly because the fixed hiring costs occur as soon as the firm decides to hire any new workers. Hence, the firm will adjust its demand for labor at once, which implies a lumpy adjustment path over time.

The structure of hiring costs can only be characterized by conducting appropriate empirical studies. Simply imposing a particular (convenient) form of hiring costs does not mean that the underlying assumption is correct, no matter how standard it has become in the literature. Empirical studies must be based on microeconomic data which describe the workers' and firms' characteristics relevant for hiring costs. We use data from two representative firm-level surveys conducted in Swiss firms, which contain detailed information on the different components of a firm's hiring costs. Our empirical results support the hypothesis that there are diseconomies of scale in recruitment, i.e., that it becomes increasingly expensive for firms to hire a larger number of skilled workers within a given time period.

The chapter is organized as follows. In the next section, we discuss the related literature and refer to a theoretical framework. Section 1.3 presents the data and provides descriptive statistics. Section 1.4 contains the empirical analysis. Section 1.5 concludes.

1.2 Related literature and theoretical framework

1.2.1 Related literature

The literature on hiring costs can be roughly divided into two parts. In the traditional part of the literature, dynamic labor demand models are used to indirectly estimate the functional form of hiring costs. Our work corresponds to a more recent part of the literature, which is based on direct empirical evidence on hiring costs.

Hamermesh and Pfann (1996) provide a summary of the early literature on factor demand models. In this literature, different forms have been proposed for the costs of adjustment associated with changing the demand for labor. In particular, the adjustment costs are predominantly assumed to be quadratic. Alternative specifications are linear adjustment costs and lumpy (i.e., fixed) adjustment costs. For a particular set of individual plants, Hamermesh (1989) finds that the standard model of convex variable adjustment costs is inferior to a specification based on fixed costs of adjustment. However, data do not allow to discriminate between different models of adjustment costs in general.

Caballero, Engel, and Haltiwanger (1997) use a different approach to analyze labor adjustment. Manufacturing establishments are assumed to adjust employment probabilistically, with adjustment probabilities being a function of the deviation between the desired and the actual level of employment. Caballero et al. (1997) and Varejão and Portugal (2007), using a similar approach, report the presence of nonconvexities in adjustment costs. These results are in line with the partial adjustment model for labor demand in King and Thomas (2006). However, Ejarque and Nilsen (2008) employing a subsample of the same Portuguese data used in Varejão and Portugal (2007) find evidence for a mainly quadratic component of adjustment costs, implying convexities. In addition, Nilsen et al. (2007), using Norwegian data finds a quadratic as well as a fixed component of adjustment costs. Merz and Yashiv (2007) estimate a model for the firms' market value using alternative convex adjustment costs specifications. With U.S. corporate sector data, they find marginal costs of hiring which are more or less equal to two quarters of wage payments.

Using British data containing information on estimated turnover costs, Manning (2006) presents evidence which implies that there are diseconomies of scale in recruitment. In contrast to our data, there is no information on wages in the British data set. Abowd and Kramarz (2003) attempt to directly estimate hiring costs using a detailed matched employer-employee data set for France. They find a large fixed-cost component in the costs of hiring workers for management positions, but none for other skill groups. However, their study does not contain any information on the productivity of newly hired workers. In our data, we find that newly hired workers will not be immediately fully productive, which is an important source of hiring costs. Kramarz and Michaud (2004) use longitudinal matched employer-employee data from France in order to estimate the shape of hiring costs. But again, data on the relative productivity of the newly hired employees are not available in their survey.
Summing up the literature on hiring costs, we conclude that despite the large theoretical literature there is no empirical study to our knowledge which directly estimates hiring costs without having to omit important components in the process.

1.2.2 Theoretical framework

The role of hiring costs in the decision-making process of the firm is illustrated by the following intertemporal profit maximization problem:

$$\max_{R_t} \Pi = \sum_{t=0}^{\infty} \beta^t \left[F(N_t) - w_t N_t - H(R_t, N_t) R_t\right]$$

subject to the constraint

$$N_{t+1} = (1-s)N_t + R_t$$

where s is the separation rate, i.e., the percentage of skilled workers that leave the firm per period, with $0 \leq s \leq 1$. $\beta = \frac{1}{1+r}$ is the discount factor.
$H(R, N)$ denotes the costs of recruiting and training a worker. These costs depend firstly on the number of recruits R. We do not specify a functional

form of H with respect to R. As well, H depends on the number of skilled workers N that are already employed by the firm. On the one hand, firms with a large N might have a different structure of the recruitment process. On the other hand, firms with a large N might be more attractive because they provide better career opportunities, which in turn would make it easier for such firms to hire additional workers.

1.3 Data

1.3.1 Survey design and data

The data used in our study are from two representative firm-level surveys conducted in Swiss firms in the years 2000 and 2004 by the Center for Research in Economics of Education at the University of Bern and the Swiss Federal Statistical Office. For the empirical analysis, we pool the two data sets, which provides information on hiring costs for a total of 4032 firms.[2]

The firms were asked about the number of skilled workers with a vocational degree that they have hired in the previous three years. The questionnaires were filled out either by management or the human resources department. The answers reflect average costs of hiring a skilled worker with a vocational degree on the external labor market. The survey was stratified by firm size and the two-digit-industry level.[3] The firms were asked to fill out hiring costs for a specific profession, which makes it easier to compare hiring costs across firms, since the comparisons can be made within a homogenous profession rather than across different occupations only.[4]

[2]Public firms and non-profit organizations have been excluded from the sample since the principle of profit-maximization does not fully apply to those firms.

[3]The industry level is defined according to NOGA, as proposed by the Swiss Federal Statistics Office. All tables that are presented in this chapter have been weighted with the corresponding survey weights that were provided by the Swiss Federal Statistics Office. For details on the construction of the weights see Potterat (2006).

[4]Firms were randomly assigned to fill out the questionnaire for a certain profession.

1.3.2 Calculation of hiring costs

The calculation of hiring costs consists of two parts, the costs of recruiting a worker, subsequently denoted by r, and the costs of initial training that is necessary to adapt to the new job, subsequently denoted by a.
Firstly, the recruiting costs consist of the costs for posting a vacancy (v_i), the costs of the time that is needed to process interviews with applicants, as well as the costs for external advisors or placement agencies (e_i). More formally, costs for a single recruit i can be written as

$$r_i = v_i + J_i c_{ai} + e_i$$

where J_i is the number of applicants per vacancy that are invited for an interview, and c_{ai} denotes the costs to conduct a single interview, which is the product of the time spent (in hours per worker) to interview an applicant times the corresponding wage of the workers involved in the interview process.[5]
Secondly, there are costs to the firm that arise because a newly appointed skilled worker will not immediately be fully productive. In the questionnaire, firms were asked for how many days d_{ai} a new worker is less productive than an average skilled worker in the firm. The relative productivity is denoted by p_i. There are several reasons why a newly hired worker is less productive initially. A possible explanation is firm specific human capital, which first has to be acquired before a worker can be fully productive, such as getting to know the firm environment, production processes and colleagues. Other reasons for lower productivity might be that newly hired workers receive training away from the workplace. This is costly to the firm in two ways: first, the firm has to pay the worker the daily salary w_{di} during the number of training days d_{ti}, and second, there are direct training costs c_{ti} for internal or external training personnel, travel costs or course fees. As a result, adaptation costs a_i can be written as

$$a_i = d_{ai}(1 - p_i)w_i + d_{ti}w_i + c_{ti}$$

Hence, the hiring costs[6] in firm i to fill a vacancy are given by

$$H_i = r_i + a_i$$

[5]There are five different job categories for interviewers: management, skilled workers with a vocational degree (by subcategories: administration, technical or social, crafts) and workers with no vocational degree.

[6]Sometimes there is criticism against constructing a LHS-variable. But the only alternative

1.3.3 Descriptive Statistics

The descriptive statistics in the appendix (Table 1.A1) show that on average, hiring costs H to fill a vacancy are CHF 13,500. There is considerable variation, since the maximum hiring costs are above CHF 170,000, which equals about two years of a worker's salary, while other firms have hiring costs of practically zero.[7] This variation is of interest for obvious reasons and will be explored later on. Adaption costs a are, on average, accountable for about 70% of total hiring costs. In turn, the main component of adaption costs is the costs associated with lower productivity during the adaption period.

The remaining 30% of hiring costs are due to recruitment costs. About half of the recruitment costs are caused by processing interviews with job-applicants. While a single interview costs on average only somewhat less than CHF 400, total interview costs are considerably higher because, on average, a firm interviews about 5 applicants to fill a single vacancy. The costs for external advisors or placement agencies are quite low on average, and amount to about 10% of recruitment costs, but can still be large for a single firm that uses such services, since the maximum amount paid for external placement agencies amounts to CHF 30,000.

Figure 1.A1 shows a histogram of the hiring costs. The distribution of H is skewed to the right with about 50% of the observations lying between 5,000 and 17,000 CHF.

While overall averages give a first indication about hiring costs, we need to explore the data in more detail. In a first step, the descriptive statistics are presented by firm size categories (Table 1.1). The total hiring costs H increase rather strongly by firm size. Very small firms with less than 10 employees spend on average 12,000 CHF to fill a vacancy, while large firms with 100 or more employees have to bear hiring costs that are almost twice as high.

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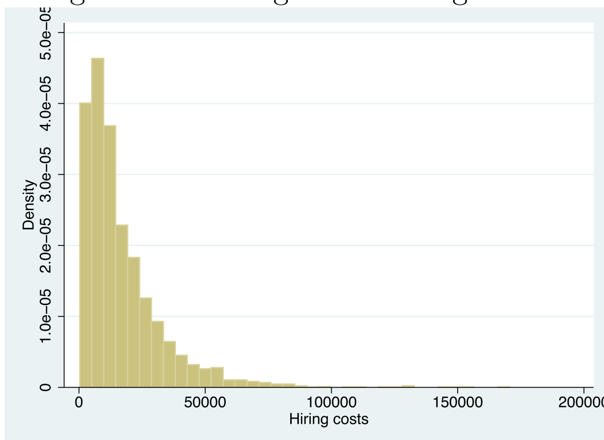
would be to directly ask the firms about the monetary costs of hiring skilled workers. The problem with this approach would be that firms might use different accounting procedures to internally calculate their costs. In our case, the hiring costs are calculated in exactly the same way for all firms, which makes comparison much more reliable.

[7] The model of Mortensen (2003) predicts marginal hiring costs equal to two years of a worker's salary for a firm paying the median wage in Denmark.

Figure 1.1: Histogram of hiring costs H



The recruitment costs r increase strongly with firm size. Firms with 100 and more employees face recruitment costs that are on average almost four times higher than those of the smallest firms. This is mainly due to higher costs for posting vacancies and higher per-applicant interview costs.

There are two reasons why the interview costs are higher for larger firms. Firstly, large firms spend more time interviewing an applicant than smaller firms (see Table 1.A2). On average, the smallest firms spend about 6.4 hours per applicant.[8] Large firms with 100 or more employees spend twice as much time to interview a single job-applicant. Different categories of workers are involved in conducting an interview with an applicant. On average, more than 50% of the interview costs can be attributed to the time spent by skilled workers and about 40% to the time spent by management. The second reason why interview costs are higher for large firms is that the salary of the workers conducting the interview is higher in large firms (see Table 1.A3). The biggest difference in median salary across the different firm size categories is observed for management positions. Small firms pay a median hourly wage of CHF 56.3, while firms in the largest firm size group pay a corresponding wage of CHF 73.3, which amounts to a wage differential of 30%. Skilled workers with a vocational degree in the largest firm size category earn 20% more than their colleagues in the smallest firms. The differences in wages for workers with no vocational

[8]This includes time for preparation of the interview, the interview itself, time for review and time necessary for administrative work.

Table 1.1: Descriptive statistics by firm size

Number of employees:	1-9	10-49	50-99	100+
Costs for job postings v	724	1571	2300	3235
Costs for interview per applicant c_a	317	505	565	770
No. of interviewed applicants J	4.7	4.9	4.7	5.4
Personnel costs for interviews Jc_a	1603	2560	2785	4388
Costs for external advisors e	246	584	1125	1516
Recruitment costs $r = v + Jc_a + e$	2744	5225	7852	10329
Adaption period in days d_a	81	77	82	82
Decline in productivity $(1 - p)$(in %)	28	30	31	33
Daily wage w of a skilled worker	338	365	378	394
Training courses in days d_t	1.4	1.7	2.6	2.5
Direct training costs c_t	454	627	1030	1302
Adaption costs $a = d_a(1 - p)w + d_t w + c_t$	9098	10406	11875	12736
Average hiring costs	11847	15633	19727	23065
Observations	1481	1054	682	815

degree are not as pronounced. As a conclusion, the main reason why large firms have higher interview costs per applicant is that they spend more time interviewing applicants, and - to a much smaller extent - that the workers who conduct the interviews earn higher wages, which makes interview time itself more costly.

While larger firms spend more time interviewing job-applicants, they do not invite significantly more applicants to a job interview for a single vacancy. On average, firms interview about five candidates; only the largest firms invite slightly more job-candidates. This indicates that larger firms select their applicants more carefully, since they spend more time on a given number of applicants. Furthermore, large firms make use of external advisors or headhunters to fill a vacancy more frequently than small firms.

While recruitment costs differ substantially by firm size, adaption costs (a) increase only slightly for larger firms (see Table 1.1). The adaption period d_a, during which newly hired workers are less productive compared to an average skilled worker in the corresponding firm, usually lasts about 80 days and does not differ significantly by firm size. The average productivity-loss compared to an average skilled worker within a firm is on average about 30%, and increases only slightly in firm size. The main reason why adaption costs are higher for large firms is the higher wage costs of skilled workers. The daily wage costs for a skilled worker with a vocational degree in a small firm are CHF 338, while they are CHF 394 for a firm with 100 or more employees. As well, newly hired workers in large firms spend more time in training courses. The direct costs for training are quite low and amount to about CHF 1300 in the largest firm size category.

The average hiring costs also differ substantially with respect to industry (Table 1.A4), sector (Table 1.A5) and profession in which a worker is hired (Table 1.A6). For example, average hiring costs in the banking and insurance industry are equal to CHF 25,000, whereas hiring costs in the textile industry are below CHF 8,000 on average. Considering different professions, hiring costs for an IT specialist are about four times the hiring costs of a cook. However, the respective shares of the recruitment and adaption costs do not differ to the same degree. On average, 30% of hiring costs are due to recruitment of workers, whereas adaption costs account for the remaining 70%.

Detailed descriptive statistics of all other variables used in the analysis are given in Table 1.A7.

1.4 Econometric models and empirical analysis

In this section, we empirically estimate the shape of the hiring costs function H, introduced in section 1.2.2. We begin by estimating a bivariate nonparametric regression model with respect to the number of recruits R, without making any assumptions about the functional form of H. This provides first insights concerning the relationship between hiring costs and the number of recruits and motivates the parametric specification of the multivariate regression model in the next subsection.

1.4.1 Nonparametric analysis

In this subsection, we estimate the functional form of the hiring costs, using local polynomial regression estimators.
The regression model for the firms $i = 1, ...N$ is of the form

$$y_i = m(x_i) + \varepsilon_i$$

In our case, y_i denotes the hiring costs and x_i denotes the number of recruits. We are interested in the functional form $m(x)$, which is linear in the neighborhood of x_0, such that $m(x) = a_0 + b_0(x - x_0)$ in the neighborhood of x_0.[9] The local linear regression estimator minimizes

$$\sum_{i=1}^{N} K\left(\frac{x_i - x_0}{h}\right)(y_i - a_0 - b_0(x_i - x_0))^2,$$

with respect to the parameters a_0 and b_0, where K denotes the Kernel weighting function. As a result, $\hat{m}(x) = \hat{a}_0 + \hat{b}_0(x - x_0)$ in the neighborhood of x_0.
We apply an Epanechnikov Kernel with third degree polynomial in the regressions displayed in Figures 1.2 - 1.A4.[10]
The functional form of the hiring costs H is crucial in determining whether there are economies or diseconomies of scale in recruitment. In turn, the structure of hiring costs determines how the firms adjust their demand for labor over time. If there are economies of scale, it is optimal for a firm to hire all skilled workers at the same time. Conversely, if there are diseconomies of scale in recruitment, the optimal strategy for a firm is to adjust its labor force gradually.

Hiring costs

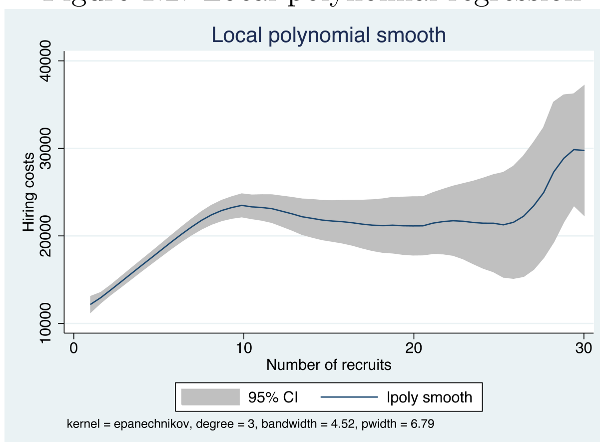
Empirically, we find that the hiring costs H to fill a vacancy are an increasing function of the number of recruits R, but that the effect diminishes as the number of recruits R becomes large (see Figure 1.2). Increasing average costs in turn imply that the marginal costs are increasing in R. This indicates that it becomes increasingly expensive for a firm to hire additional workers in a given

[9] See Cameron and Trivedi (2006), p. 320.

[10] It should be noted that 95% of the firms have a value of $R < 10$. The estimations were carried out in Stata using the -lpoly- command.

time period. Moreover, this means that the total hiring costs are a convex function of the number of recruits.

Figure 1.2: Local polynomial regression



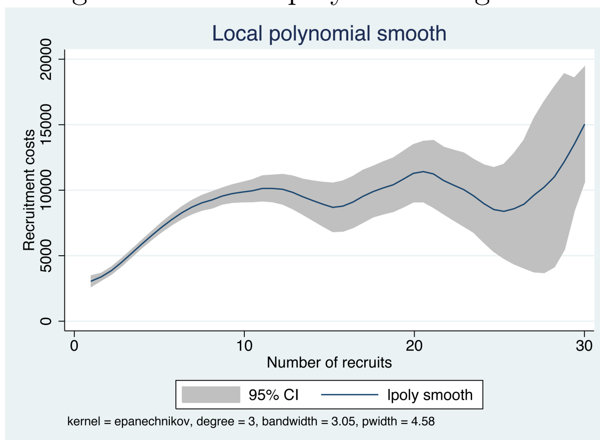
Average hiring costs also increase in the number of skilled workers N (see Figure 1.A2). However, firms with a large number of skilled workers typically also hire a large number of recruits in a given time period. Hence, it is necessary to carry out a multivariate analysis in order to separate the effects of R and N on H. This will be provided in the next section.

Recruitment costs

To get a better understanding of how the number of recruits R hired in a given time period and the number of skilled workers N employed by a firm affect hiring costs H, we estimate the non-parametric regressions shown above also for the different components of hiring costs. Figure 1.3 shows that the effect of the number of recruits on average recruitment costs is similar to the effect on overall hiring costs: average and hence marginal recruitment costs increase in the number of recruits.

The same is true for the effect of the number of skilled workers N on the recruitment costs: firms with a higher N face higher recruitment costs (see Figure 1.A3).

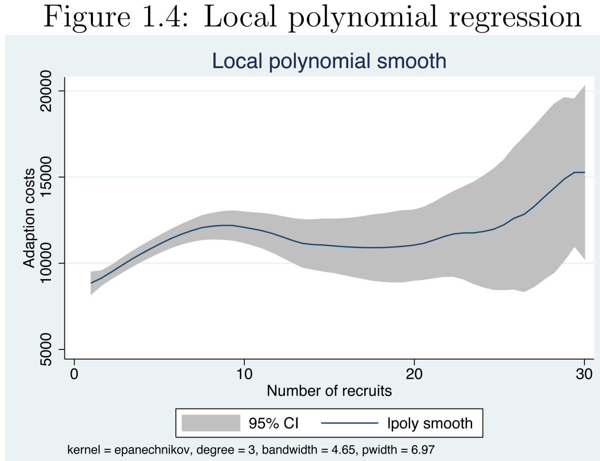
Figure 1.3: Local polynomial regression



Adaption costs

In contrast to recruitment costs, adaption costs are less affected by both the number of recruits and the number of skilled workers. Nevertheless, adaption costs are still increasing at low numbers of R and N, but remain roughly constant for higher values of R and N (see Figure 1.4 and Figure 1.A4).

Figure 1.4: Local polynomial regression



Non-parametric estimates provide first insights about the relation between hiring costs on the one hand and the number of recruits as well as the number of skilled workers on the other hand. However, for a meaningful interpretation of the results we need to go beyond a simple bivariate analysis.

1.4.2 Multivariate parametric analysis

Since the use of nonparametric estimation techniques is restricted when the number of regressors becomes large, we estimate parametric multivariate ordinary least squares regressions of the form below:

$$y_i = \alpha_0 + \beta R + \gamma N + \delta \mathbf{x} + u_i, \quad i = 1, ..., N$$

where $\mathbf{x}$ includes the following control variables: firm size (measured by the number of employees other than N), wages, macroeconomic conditions [11], industry,[12] different occupations and a time dummy indicating the year of the survey.

The focus of our analysis lies on the effect of R on hiring costs and its components. We estimate different model specifications with respect to the control variables used in the regressions and perform level-level and log-level regressions.

Hiring costs

Since the distribution of H is right-skewed, we use $\ln H$ as the dependent variable. A histogram of $\ln H$ is shown in Figure 1.A1. The summary of the regression results is reported in Table 1.2.[13]

The effect of R on hiring costs is positive and significant throughout the various model specifications. In the baseline model (1), only R and higher order terms of R have been included. The linear effect of R is equal to 0.13, meaning that if R increases by 1, average hiring costs increase by 13%. However, the quadratic term is negative and significant, which implies that the effect is diminishing at higher values of R. The third order term of R is also significant, but positive, meaning that hiring costs eventually increase again in R. The total marginal effect of R is equal to 10% in model (1), evaluated at the average value of R, which is equal to 2.79. At a value of R equal to 20, H reaches a predicted maximum of about 20,700 CHF and then decreases. It should be noted, however,

[11] The cantonal incomes serve as proxy variable for macroeconomic conditions.

[12] The industry level is defined at the two digit-level.

[13] The detailed regression outputs reporting the coefficients of the industry and occupation variables are presented in Table 1.A8. The results of the level-level estimations are presented in Table 1.A9.

that 95% of the firms in our sample have a value of $R < 10$, hence H is increasing in R for almost all observed firms.

As already discussed in the bivariate analysis in the previous section, hiring costs are increasing in the number of skilled workers N as well. In model (2), we therefore include the variables N and other workers employed by the firm. The results show that H is increasing both in N and other employees, indicating that it is more costly for larger firms to hire skilled workers. In addition, we included interaction terms of both variables with R, because it can be suspected that larger firms generally recruit more workers in a given time period compared to smaller firms. We find that the interaction terms with R are indeed significant and negative. This indicates that hiring an additional skilled worker is relatively more expensive for smaller firms compared to larger firms. The economic intuition behind this finding is that small firms recruiting a large number of skilled workers have a different organizational structure than large firms which are used to recruit many workers. For example, large firms typically have a human resources department, which makes extensive recruiting more cost efficient. Even though the firm size affects average hiring costs, the coefficient on R remains robust and is equal to 0.12.

Furthermore, a number of other control variables have been included in the model specifications (3)-(5). The results show that the wage of a skilled worker positively influences H. This is not surprising, because a higher wage increases the adaption costs. In addition, wages of different worker groups within a firm are typically correlated. Hence, a high wage for skilled workers often comes along with high wages of the persons conducting job interviews, which in turn increases recruitment costs.

The economic situation is likely to affect hiring costs as well. For instance, in a period of economic boom, it might be more difficult, and hence more costly, to find suitable skilled workers on the labor market. To control for this effect, we included the regional unemployment rate in the estimation. As expected, the coefficient is negative and significant. We also added the aggregate per-capita income to control for economic wealth of the region in which the firm is operating. The coefficient is positive and significant, indicating that skilled labor might be more scarce in such regions.

Furthermore, we have included dummy variables for the industrial sector and

Table 1.2: Hiring costs regressions

ln(Hiring costs)	(1)	(2)	(3)	(4)	(5)
Number of recruits R	0.12707	0.11503	0.09864	0.08920	0.08932
	(0.01873)	(0.02562)	(0.02435)	(0.02314)	(0.02273)
R^2	-0.00414	-0.00464	-0.00381	-0.00364	-0.00379
	(0.00076)	(0.00127)	(0.00124)	(0.00119)	(0.00119)
$R^3 \cdot 10^3$	0.03340	0.04560	0.03760	0.03630	0.00004
	(0.00737)	(0.01660)	(0.01630)	(0.01520)	(0.00002)
Number of skilled workers N		0.01854	0.00457	0.00218	0.00130
		(0.00483)	(0.00430)	(0.00375)	(0.00373)
$R \cdot N$		-0.00195	-0.00083	-0.00065	-0.00061
		(0.00049)	(0.00044)	(0.00039)	0.00039
$R^2 \cdot N$		0.00007	0.00004	0.00003	(0.00003)
		(0.00002)	(0.00002)	(0.00001)	0.00001
$R^3 \cdot N \cdot 10^3$		-0.00063	-0.00040	-0.00036	-(0.00036)
		(0.00018)	(0.00017)	(0.00015)	0.00015
Employees other than N		0.00244	0.00223	0.00181	(0.00144)
		(0.00035)	(0.00028)	(0.00027)	0.00028
$R\cdot$(Employees other than N)		-0.00011	-0.00011	-0.00009	-(0.00006)
		(0.00003)	(0.00003)	(0.00002)	0.00002
Daily wage of a skilled worker			0.00406	0.00397	0.00363
			(0.00027)	(0.00027)	(0.00027)
Aggregate regional income$\cdot 10^3$				0.00527	0.00441
				(0.00189)	(0.00185)
Regional unemployment rate				-0.05423	-0.03857
				(0.02060)	(0.02088)
Industry controls	No	No	No	Yes	Yes
Profession controls	No	No	No	No	Yes
Constant	8.78593	8.85088	7.49406	7.58415	7.58609
	(0.04906)	(0.05715)	(0.11050)	(0.14596)	(0.14505)
R^2	0.031	0.058	0.153	0.276	0.301
Observations	4032	4032	4032	4032	4032

Robust standard errors in parentheses. The reference category is a firm in the mining industry and surveyed in the year 2004.

the profession in which recruited skilled workers are employed. While there are some substantial differences between industries and professions, the effect of R on H remains positive and significant, but decreases slightly in models (4) and (5).

Finally, we present quantile regression models. The results show that the coefficient on R remains positive and highly significant (see Table 1.A10). The effect of R on H is strongest at the 25% quantile with a value of 0.27. The effect at the median is 0.22 and at the 75% quantile 0.1. Hence, the marginal costs of hiring additional workers increase more at the lower quartile than at higher quartiles.

Recruitment costs

The effect of R on recruitment costs is positive and significant throughout the different model specifications (see Table 1.A11). Compared to the estimates on total hiring costs, the coefficient on R is roughly twice as high. This means that recruitment costs increase by more than adaption costs. An economic interpretation of this finding is that skilled workers on the external labor market become scarce, which forces firms to intensify their search effort and in turn increases their recruitment costs.

The results are also economically significant: At the average value of R, an additionally hired worker increases average recruitment costs by approximately 22% in model (1). This implies that marginal recruitment costs increase by even more.

Another effect worth mentioning is the regional unemployment rate. It has a stronger effect on recruitment costs compared to hiring costs. A 1%-point increase in the regional unemployment rate leads to a decrease in average recruitment costs of about 10%. This underlines the importance of labor market conditions. Firms find it easier to fill a vacancy if skilled workers are readily available on the external labor market.

Adaption costs

The results for the adaption costs are shown in Table 1.A12. Again, we find a significant effect of R throughout the various models. The size of the effect

of R on adaption costs is slightly lower than its effect on total hiring costs. In model (1), the total marginal effect is equal to 9% at the average value of R.
The explanation of these results is that adaption costs are not as closely tied to the situation on the external labor market as recruitment costs. However, if a firm hires many new workers in a given time period, the average match quality may be lower, which in turn results in a prolonged adaption period. In addition, and possibly more important, a firm's resources for training newly hired workers are limited. Hence, if many workers are hired at once, adaption becomes increasingly costly.

1.5 Conclusions

So far, only few studies have been able to directly estimate the shape of hiring costs. Instead, dynamic labor demand models have been used to indirectly estimate the functional form of hiring costs.
Based on directly observed firm-level data, we can quantify the cost of hiring skilled workers. On average, a firm has to bear a considerable amount - about a quarter of yearly wage payments - to fill a vacancy. However, hiring costs vary substantially by firm size, profession and industry. Our results suggest that the marginal costs of hiring skilled workers in a given time period are increasing in the number of recruits, which is incompatible with the presence of large fixed costs. We find that the effect is particularly strong for small firms.
Our findings help to better understand the firms' hiring behavior and suggest that the optimal hiring policy for a firm is to recruit skilled workers continuously rather than grouping the recruits. This implication is especially important in order to determine the effects of macroeconomic shocks on labor market outcomes.

1.A Appendix

1.A.1 Figures

Figure 1.A1: Histogram of logarithmic hiring costs

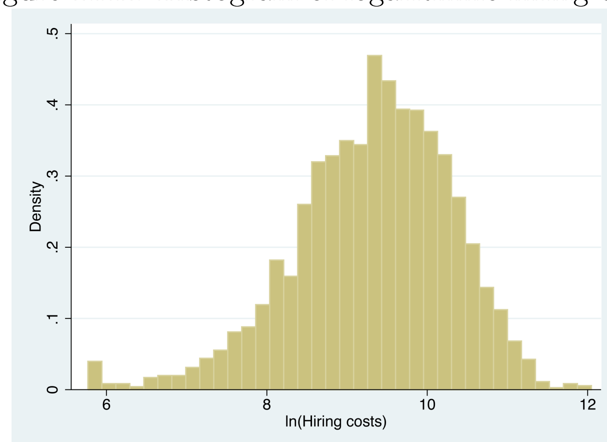


Figure 1.A2: Local polynomial regression for hiring costs

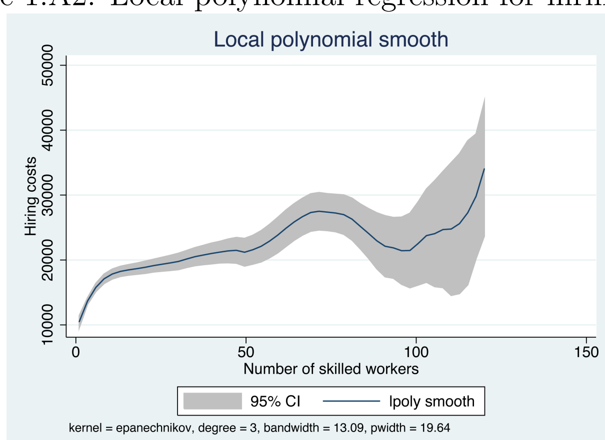


Figure 1.A3: Local polynomial regression for recruitment costs

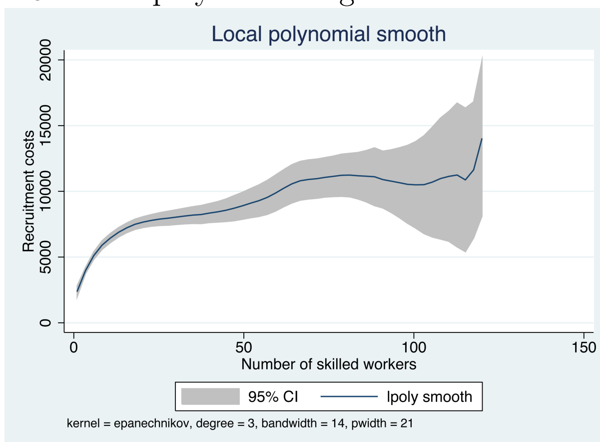
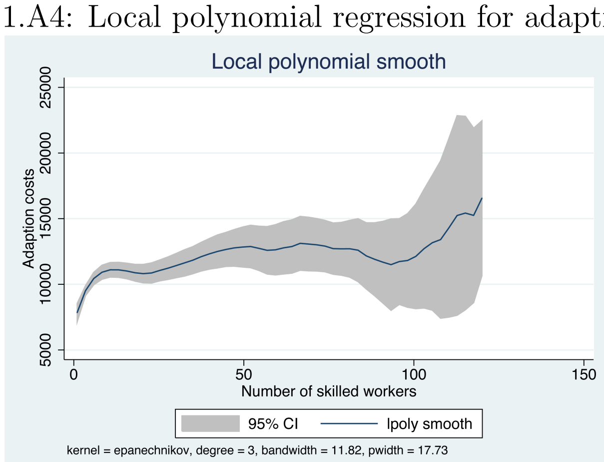


Figure 1.A4: Local polynomial regression for adaption costs



1.A.2 Tables

Table 1.A1: Descriptive statistics

Variable	Mean	Std.Err.	Minimum	Maximum	Obs.
Costs for job postings v (in CHF)	1103	1889	0	50000	4032
Costs for interview per applicant c_a (in CHF)	395	495	0	8844	4032
Number of interviewed applicants J per vacancy	5	4	1	30	4032
Personnel costs for interviews $J * c_a$	2009	3877	0	83586	4032
Costs for external advisors/headhunters e (in CHF)	414	1881	0	30000	4032
Recruitment costs $r = v + J * c_a + e$ (in CHF)	3878	5894	0	116117	4032
Duration of adaption period in days d_a	80	60	0	756	4032
Average decline in productivity $(1 - p)$ during adaption period (in %)	29	14	0	90	4032
Daily wage w of a skilled worker with vocational degree (in CHF)	349	79	125	784	4032
Duration of training courses in days d_t	2	4	0	90	4032
Direct training costs c_t (in CHF)	550	1805	0	60000	4032
Adaption costs $a = d_a * (1 - p)w + d_t * w + c_t$ (in CHF)	9688	11005	0	147779	4032
Average hiring costs $H = r + a$ to fill a vacancy (in CHF)	13570	13862	320	170575	4032

Table 1.A2: Average time spent by different worker categories to interview job-applicants to fill a vacancy (in hours)

	1-9 employees	10-49 employees	50-99 employees	100+ employees
Management	2.6	4.0	3.9	5.2
Skilled workers with vocational degree	3.1	4.7	5.0	6.6
Workers with no vocational degree	0.6	0.7	0.9	1.0
Total time to interview an applicant (in hours)	6.4	9.4	9.8	12.9
Observations	1481	1054	682	815

Table 1.A3: Median hourly wage of workers that interview job-applicants (in CHF)

	1-9 employees	10-49 employees	50-99 employees	100+ employees
Management	56.3	64.4	68.9	73.3
Skilled workers with vocational degree	39.7	42.9	44.5	46.7
Workers with no vocational degree	29.3	31.4	31.8	32.2
Observations	1481	1054	682	815

Table 1.A4: Hiring costs by industry

Variable:	Hiring costs	Share of total hiring costs	
		Recruitment costs	Adaption costs
Banking, insurance	25159	31%	69%
	(1706)		
Machine, automotive manufact.	23734	35%	65%
	(1210)		
Paper, print, media	22978	30%	70%
	(1175)		
Metal manufacturing	22856	34%	66%
	(1051)		
Real estate, IT, research	18624	28%	72%
	(644)		
Education	17287	31%	69%
	(1171)		
Food,beverages, tobacco	17093	33%	67%
	(2088)		
Chemical, oil	16378	20%	80%
	(969)		
Hotel, restaurant	13464	28%	72%
	(512)		
other services, culture, sport	13387	23%	77%
	(945)		
Crafts (Wood)	13295	48%	52%
	(1025)		
Transport, communication	12205	29%	71%
	(861)		
other manufacturing	11698	23%	77%
	(935)		
Construction	8666	32%	68%
	(1088)		
Mining	8514	26%	74%
	(377)		
Health, social institutions	7844	22%	78%
	(1171)		
Textiles, leather, shoes	7828	20%	80%
	(754)		
Trade and repair of automobiles	7445	40%	60%
	(346)		

Standard errors in parentheses.

Table 1.A5: Hiring costs by sector

Variable:	Hiring costs	Share of total hiring costs	
		Recruitment costs	Adaption costs
Industrial	16124	29%	71%
	(418)		
Services	13946	29%	71%
	(294)		
Construction	8514	26%	74%
	(377)		

Standard errors in parentheses.

Table 1.A6: Hiring costs by professions

Variable:	Hiring costs	Share of total hiring costs	
		Recruitment costs	Adaption costs
Automatician	29344	23%	77%
	(2529)		
IT specialist	29059	23%	77%
	(1801)		
Polymechanics technician	21662	23%	77%
	(1015)		
Electronics technician	19729	45%	55%
	(1779)		
Administrative assistant	19202	31%	69%
	(493)		
Electrician	13125	26%	74%
	(1330)		
Car mechanic	12332	21%	79%
	(1575)		
Sales clerk (3 years)	11598	29%	71%
	(1030)		
Hairdresser	11521	17%	83%
	(1556)		
Draftsman	9820	28%	72%
	(617)		
Sales clerk (2 years)	9442	21%	79%
	(702)		
Mason	7608	29%	71%
	(536)		
Joiner	7336	22%	78%
	(612)		
Cook	7302	42%	58%
	(426)		
Medical assistant	5932	24%	76%
	(688)		

Standard errors in parentheses.

Table 1.A7: Descriptive statistics

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Separation rate s	13.33	19.09	0	99	4032
Number of recruits R	2.79	3.11	1	90	4032
Number of skilled workers N	5.89	11.33	1	290	4032
Employees other than N	12.17	44.70	0	956	4032
Aggregate cantonal income	49152.14	10392.86	33699	82415	4032
Industry dummies:					
Construction	0.013	0.112	0	1	4032
Food,beverages, tobacco	0.004	0.062	0	1	4032
Textiles, leather, shoes	0.019	0.138	0	1	4032
Crafts (Wood)	0.010	0.098	0	1	4032
Paper, print, media	0.011	0.105	0	1	4032
Chemical, oil	0.031	0.173	0	1	4032
Metal manufacturing	0.015	0.122	0	1	4032
Machine, automotive manufact.	0.018	0.133	0	1	4032
Manufacturing, other	0.009	0.097	0	1	4032
Trade and repair of automobiles	0.263	0.440	0	1	4032
Hotel, restaurant	0.109	0.312	0	1	4032
Transport, communication	0.042	0.200	0	1	4032
Banking, insurance	0.034	0.181	0	1	4032
Real estate, IT, research	0.177	0.382	0	1	4032
Education	0.021	0.144	0	1	4032
Health, social institutions	0.057	0.232	0	1	4032
Other services	0.043	0.203	0	1	4032
Profession dummies:					
Administrative assistant	0.237	0.425	0	1	4032
Electrician	0.026	0.160	0	1	4032
IT specialist	0.035	0.183	0	1	4032
Polymechanics technician	0.023	0.149	0	1	4032
Sales Clerk (2 years of education)	0.045	0.206	0	1	4032
Sales Clerk (3 years of education)	0.041	0.199	0	1	4032
Cook	0.065	0.246	0	1	4032
Difficulties in finding skilled workers	0.398	0.489	0	1	4032
Year of data (1=2000, 0=2004)	0.478	0.500	0	1	4032

Table 1.A8: Hiring costs regressions

Dependent variable:	ln(Hiring costs)				
	(1)	(2)	(3)	(4)	(5)
Number of recruits R	0.12707	0.11503	0.09864	0.08920	0.08932
	(0.01873)	(0.02562)	(0.02435)	(0.02314)	(0.02273)
R^2	-0.00414	-0.00464	-0.00381	-0.00364	-0.00379
	(0.00076)	(0.00127)	(0.00124)	(0.00119)	(0.00119)
$R^3 \cdot 10^3$	0.03340	0.04560	0.03760	0.03630	0.00004
	(0.00737)	(0.01660)	(0.01630)	(0.01520)	(0.00002)
Number of skilled workers N		0.01854	0.00457	0.00218	0.00130
		(0.00483)	(0.00430)	(0.00375)	(0.00373)
$R \cdot N$		-0.00195	-0.00083	-0.00065	-0.00061
		(0.00049)	(0.00044)	(0.00039)	0.00039
$R^2 \cdot N$		0.00007	0.00004	0.00003	(0.00003)
		(0.00002)	(0.00002)	(0.00001)	0.00001
$R^3 \cdot N \cdot 10^3$		-0.00063	-0.00040	-0.00036	-(0.00036)
		(0.00018)	(0.00017)	(0.00015)	0.00015
Employees other than N		0.00244	0.00223	0.00181	(0.00144)
		(0.00035)	(0.00028)	(0.00027)	0.00028
R·(Employees other than N)		-0.00011	-0.00011	-0.00009	-(0.00006)
		(0.00003)	(0.00003)	(0.00002)	0.00002
Daily wage of a skilled worker			0.00406	0.00397	0.00363
			(0.00027)	(0.00027)	(0.00027)
Aggregate regional income·10^3				0.00527	0.00441
				(0.00189)	(0.00185)
Regional unemployment rate				-0.05423	-0.03857
				(0.02060)	(0.02088)
Mining				-0.77578	-0.70319
				(0.07592)	(0.08067)
Construction				-0.53322	-0.46344
				(0.10896)	0.10661
Food,beverages, tobacco				0.35091	(0.26171)
				(0.15553)	0.14182
Textiles, leather, shoes				-0.59802	-(0.52026)
				(0.12714)	0.12364
Crafts (Wood)				-0.17581	-(0.08073)
				(0.14692)	0.14621
Paper, print, media				0.36381	(0.33802)
				(0.08092)	0.08529
Chemical, oil				0.08823	0.06065
				(0.10751)	(0.11587)
Metal manufacturing				0.37532	0.38113
				(0.08643)	(0.09406)

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Machine, automotive manufact.				0.39865	0.37027
				(0.09754)	(0.10027)
other manufacturing				-0.07284	-0.06542
				(0.15686)	(0.16482)
Hotel, restaurant				-0.46573	-0.39117
				(0.07661)	0.10877
Transport, communication				-0.30280	-(0.37517)
				(0.15141)	0.15182
Banking, insurance				0.44395	(0.30093)
				(0.10360)	0.10918
Real estate, IT, research				0.09727	(0.05471)
				(0.05943)	0.06240
Education				0.25308	(0.27879)
				(0.15134)	0.15818
Health, social institutions				-0.50878	-0.42111
				(0.07820)	(0.08181)
other services, culture, sport				0.07582	0.06822
				(0.10479)	(0.10788)
Administrative assistant					0.37031
					(0.04644)
Electrician					0.19085
					(0.11550)
IT specialist					0.45652
					0.10468
Polymechanics technician					(0.19898)
					0.10708
Sales clerk (3 years)					(0.13975)
					0.09204
Sales clerk (2 years)					(0.13860)
					0.11343
Cook					-(0.10802)
					0.12332
Year 2000 (1=yes/0=no)		-0.23987	-0.17403	-0.10201	-0.11333
		(0.04483)	(0.04281)	(0.04664)	(0.04744)
Constant	8.78593	8.85088	7.49406	7.58415	7.58609
	(0.04906)	(0.05715)	(0.11050)	(0.14596)	(0.14505)
R^2	0.031	0.058	0.153	0.276	0.301
Observations	4032	4032	4032	4032	4032

Robust standard errors in parentheses. The reference category is a firm in the mining industry and surveyed in the year 2004.

Table 1.A9: Hiring costs regressions

Dependent variable:	Hiring costs				
	(1)	(2)	(3)	(4)	(5)
Number of recruits R	1714.699	1390.463	1123.500	1029.269	1009.90400
	(275.327)	(348.177)	(313.191)	(291.981)	(285.73000)
R^2	-50.774	-51.969	-38.476	-37.553	-37.89133
	(13.592)	(17.278)	(15.662)	(15.031)	(14.87635)
$R^3 \cdot 10^3$	391.179	492.413	362.907	360.072	0.37176
	(131.259)	(194.885)	(182.534)	(172.045)	(0.17139)
Number of skilled workers N		311.145	83.687	46.912	47.809
		(95.905)	(82.783)	(76.938)	(76.864)
$R \cdot N$		-29.003	-10.736	-8.303	-8.682
		(8.913)	(7.697)	(7.155)	(7.147)
$R^2 \cdot N$		0.995	0.495	0.436	0.432
		(0.281)	(0.247)	(0.232)	(0.232)
$R^3 \cdot N \cdot 10^3$		-8.665	-4.909	-4.525	-4.475
		(2.690)	(2.415)	(2.267)	(2.269)
Employees other than N		28.617	25.184	20.812	14.739
		(7.838)	(6.983)	(7.140)	(7.610)
$R \cdot$(Employees other than N)		-1.465	-1.423	-1.172	-0.738
		(0.537)	(0.476)	(0.462)	(0.477)
Daily wage of a skilled worker			66.049	65.905	59.330
			(5.319)	(5.859)	(5.837)
Aggregate regional income$\cdot 10^3$				78.380	66.740
				(28.558)	(27.489)
Regional unemployment rate				-973.557	-760.621
				(263.136)	(265.970)
Mining				-9115.246	-8266.722
				(920.044)	(964.935)
Construction				-5914.437	-5133.056
				(1191.353)	(1162.984)
Food,beverages, tobacco				3025.928	1934.966
				(2668.284)	(2523.266)
Textiles, leather, shoes				-8761.384	-7889.252
				(1305.468)	(1205.091)
Crafts (Wood)				-5859.481	-4717.146
				(1914.463)	(1897.249)
Paper, print, media				3872.247	3530.265
				(1696.848)	(1724.322)
Chemical, oil				-669.496	-1131.595
				(1484.346)	(1445.370)
Metal manufacturing				3907.374	3901.663
				(1654.544)	(1708.580)

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Machine, automotive manufact.				5374.683	4962.881
				(2002.391)	(2016.259)
other manufacturing				-3909.353	-3880.416
				(1907.894)	(1955.807)
Hotel, restaurant				-5957.263	-5134.990
				(757.265)	(966.402)
Transport, communication				-4393.660	-5540.043
				(1310.711)	(1422.039)
Banking, insurance				6570.401	4797.194
				(2142.266)	(2256.390)
Real estate, IT, research				900.171	-207.369
				(954.223)	(983.938)
Education				1163.049	1335.476
				(1262.497)	(1418.439)
Health, social institutions				-4921.952	-4043.146
				(1119.242)	(1192.600)
other services, culture, sport				368.241	49.189
				(1161.103)	(1230.096)
Administrative assistant					4436.962
					(699.704)
Electrician					1972.377
					(1863.259)
IT specialist					9735.960
					(2275.829)
Polymechanics technician					2579.888
					(1647.883)
Sales clerk (3 years)					990.396
					(1273.319)
Sales clerk (2 years)					345.329
					(1129.523)
Cook					-1299.351
					(1030.917)
Year 2000 (1=yes/0=no)		-1398.973	-326.950	891.473	759.194
		(568.495)	(543.555)	(672.146)	(676.139)
Constant	9531.283	9672.903	-12418.960	-11320.010	-10368.190
	(611.669)	(710.713)	(1908.077)	(2337.996)	(2366.016)
R^2	0.034	0.051	0.185	0.281	0.307
Observations	4032	4032	4032	4032	4032

Robust standard errors in parentheses. The reference category is a firm in the mining industry and surveyed in the year 2004.

Table 1.A10: Quantile Regressions

Dependent variable:		$\ln H$	
	$Q_{25\%}$	$Q_{50\%}$	$Q_{75\%}$
$\ln R$	0.2702	0.2195	0.0955
	(0.0431)	(0.0158)	(0.0247)
$\ln N$	-0.0789	-0.0659	0.0262
	(0.0293)	(0.0111)	(0.0173)
ln (Employees other than N)	0.0209	0.0090	0.0103
	(0.0042)	(0.0016)	(0.0025)
$\ln w$	1.3317	1.4049	1.3577
	(0.0958)	(0.0358)	(0.0594)
ln(Aggregate regional income)	0.3492	0.2476	0.1047
	0.0892	(0.0347)	(0.0556)
Construction	0.2595	0.1507	-0.0090
	(0.1352)	(0.0491)	(0.0677)
Food,beverages, tobacco	1.2594	0.9336	0.8330
	(0.1656)	(0.0657)	(0.1137)
Textiles, leather, shoes	0.3746	0.2309	0.1268
	(0.1257)	(0.0483)	(0.0813)
Crafts (Wood)	0.6217	0.6146	0.4765
	(0.1548)	(0.0556)	(0.0814)
Paper, print, media	1.0987	1.1912	1.0099
	(0.0997)	(0.0367)	(0.0600)
Chemical, oil	0.8502	0.7687	0.6983
	(0.1107)	(0.0420)	(0.0663)
Metal manufacturing	1.1114	1.1298	1.0347
	(0.1013)	(0.0394)	(0.0638)
Machine, automotive manufacturing	1.2137	1.0649	0.9604
	(0.0985)	(0.0396)	(0.0642)
Manufacturing office equipment, medical	0.6852	0.7017	0.5372
	(0.1424)	(0.0555)	(0.0920)
Trade and repair of automobiles	0.7894	0.7562	0.5915
	(0.0658)	(0.0250)	(0.0398)
Hotel, restaurant	0.6066	0.2293	0.2252
	(0.1110)	(0.0411)	(0.0652)
Transport, communication	0.4081	0.6110	0.3478
	(0.1262)	(0.0465)	(0.0685)
Banking, insurance	1.0638	1.1571	0.8565
	(0.1144)	(0.0435)	(0.0701)
Real estate, IT, research	0.9225	0.8748	0.7096
	(0.0648)	(0.0242)	(0.0381)
Education	1.3380	1.1247	0.8577
	(0.1574)	(0.0601)	(0.0946)

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Health, social institutions	0.3883			0.3546	0.2380
	(0.0808)			(0.0307)	(0.0482)
other services, culture, sport, entertainment	0.9345			0.8596	0.6953
	(0.0979)			(0.0372)	(0.0570)
Administrative assistant	0.3238			0.2372	0.3243
	(0.0450)			(0.0172)	(0.0273)
Electrician	0.0589			0.0773	0.1257
	(0.1061)			(0.0399)	(0.0607)
IT specialist	0.3805			0.4213	0.4832
	(0.0983)			(0.0360)	(0.0563)
Polymechanics technician	0.2444			0.0932	-0.0835
	(0.1086)			(0.0405)	(0.0641)
Sales clerk (3 years)	-0.0829			0.0596	0.0582
	(0.0963)			(0.0375)	(0.0597)
Sales clerk (2 years)	0.1337			0.0454	0.0609
	(0.1079)			(0.0406)	(0.0644)
Cook	-0.3384			-0.0809	-0.1417
	(0.1253)			(0.0459)	(0.0725)
Difficulties in finding skilled workers	0.1588			0.1322	0.2230
	(0.0370)			(0.0142)	(0.0230)
Survey in year 2000 (1=yes/0=no)	-0.2814			-0.2042	0.0121
	(0.0372)			(0.0139)	(0.0225)
Constant	-7.5354			-6.4996	-4.1912
	(1.1980)			(0.4546)	(0.7741)
R^2	0.182			0.217	0.224
Observations	4032			4032	4032

Robust standard errors in parentheses. The reference category is a firm in the mining industry and surveyed in the year 2004.

Table 1.A11: Recruitment costs regressions

Dependent variable:	ln(Recruitment costs)				
	(1)	(2)	(3)	(4)	(5)
Number of recruits R	0.27515	0.26379	0.24891	0.22530	0.19196
	(0.03110)	(0.04067)	(0.04046)	(0.03921)	(0.02617)
R^2	-0.00954	-0.01089	-0.01014	-0.00933	-0.00699
	(0.00121)	(0.00203)	(0.00205)	(0.00200)	(0.00142)
$R^3 \cdot 10^3$	0.08020	0.10920	0.10200	0.09550	0.00007
	(0.01190)	(0.02870)	(0.02880)	(0.02770)	(0.00002)
Number of skilled workers N		0.02869	0.01601	0.02137	0.01464
		(0.00734)	(0.00722)	(0.00673)	(0.00470)
$R \cdot N$		-0.00370	-0.00269	-0.00305	-0.00200
		(0.00077)	(0.00075)	(0.00072)	0.00049
$R^2 \cdot N$		0.00014	0.00011	0.00012	(0.00008)
		(0.00003)	(0.00003)	(0.00003)	0.00002
$R^3 \cdot N \cdot 10^3$		-0.00131	-0.00110	-0.00114	-(0.00070)
		(0.00032)	(0.00031)	(0.00030)	0.00018
Employees other than N		0.00504	0.00485	0.00393	(0.00301)
		(0.00065)	(0.00057)	(0.00053)	0.00040
$R\cdot$(Employees other than N)		-0.00022	-0.00021	-0.00018	-(0.00015)
		(0.00005)	(0.00005)	(0.00004)	0.00003
Daily wage of a skilled worker			0.00368	0.00380	0.00344
			(0.00039)	(0.00041)	(0.00035)
Aggregate regional income$\cdot 10^3$				0.01350	0.01140
				(0.00300)	(0.00211)
Regional unemployment rate				-0.10938	-0.08442
				(0.03206)	(0.02463)
Mining				-0.91779	-0.72997
				(0.13738)	(0.08990)
Construction				-0.33694	-0.50965
				(0.17518)	0.16128
Food,beverages, tobacco				0.58969	(0.38169)
				(0.31775)	0.28801
Textiles, leather, shoes				-0.70376	-(0.88873)
				(0.17565)	0.17607
Crafts (Wood)				0.31977	(0.20313)
				(0.18645)	0.18579
Paper, print, media				0.31883	(0.26325)
				(0.18436)	0.12540
Chemical, oil				-0.25395	-0.12524
				(0.20706)	(0.12684)
Metal manufacturing				0.55722	0.44351
				(0.14454)	(0.13744)

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Machine, automotive manufact.				0.55863	0.35486
				(0.16663)	(0.15448)
other manufacturing				-0.07530	-0.31836
				(0.15680)	(0.15321)
Hotel, restaurant				0.12284	-0.06223
				(0.12888)	0.12493
Transport, communication				-0.08062	-(0.22807)
				(0.21128)	0.15067
Banking, insurance				0.46486	(0.18188)
				(0.16342)	0.14760
Real estate, IT, research				0.17082	(0.16079)
				(0.11272)	0.07655
Education				0.52295	(0.54154)
				(0.32528)	0.14411
Health, social institutions				-0.34269	-0.45577
				(0.11959)	(0.09280)
other services, culture, sport				0.01740	-0.01580
				(0.18145)	(0.11228)
Administrative assistant					0.32780
					(0.05893)
Electrician					0.24581
					(0.13138)
IT specialist					-0.03125
					0.13058
Polymechanics technician					-(0.10029)
					0.13108
Sales clerk (3 years)					-(0.10258)
					0.14189
Sales clerk (2 years)					-(0.24436)
					0.12758
Cook					(0.03505)
					0.14931
Year 2000 (1=yes/0=no)		-0.12042	-0.06065	0.10599	-0.10385
		(0.07098)	(0.07007)	(0.07557)	(0.05563)
Constant	6.82385	6.79058	5.55897	5.23095	5.70090
	(0.08101)	(0.09592)	(0.16057)	(0.23135)	(0.16587)
R^2	0.052	0.071	0.101	0.167	0.302
Observations	4032	4032	4032	4032	4032

Robust standard errors in parentheses. The reference category is a firm in the mining industry and surveyed in the year 2004.

Table 1.A12: Adaption costs regressions

Dependent variable:	ln(Adaption costs)				
	(1)	(2)	(3)	(4)	(5)
Number of recruits R	0.11414	0.12111	0.10394	0.09735	0.10119
	(0.04015)	(0.05506)	(0.05428)	(0.05436)	(0.05377)
R^2	-0.00427	-0.00658	-0.00571	-0.00571	-0.00626
	(0.00161)	(0.00271)	(0.00271)	(0.00271)	(0.00268)
$R^3 \cdot 10^3$	0.03730	0.07930	0.07100	0.07110	0.00008
	(0.01480)	(0.03480)	(0.03460)	(0.03380)	(0.00003)
Number of skilled workers N		0.02774	0.01311	0.00939	0.00658
		(0.00867)	(0.00820)	(0.00791)	(0.00791)
$R \cdot N$		-0.00328	-0.00211	-0.00187	-0.00174
		(0.00092)	(0.00086)	(0.00083)	0.00083
$R^2 \cdot N$		0.00012	0.00009	0.00009	(0.00008)
		(0.00004)	(0.00003)	(0.00003)	0.00003
$R^3 \cdot N \cdot 10^3$		-0.00119	-0.00095	-0.00092	-(0.00092)
		(0.00037)	(0.00036)	(0.00034)	0.00035
Employees other than N		0.00246	0.00224	0.00187	(0.00122)
		(0.00047)	(0.00046)	(0.00047)	0.00049
$R\cdot$(Employees other than N)		-0.00009	-0.00009	-0.00007	-(0.00002)
		(0.00004)	(0.00004)	(0.00004)	0.00004
Daily wage of a skilled worker			0.00425	0.00433	0.00386
			(0.00048)	(0.00049)	(0.00050)
Aggregate regional income$\cdot 10^3$				0.00123	-0.00021
				(0.00498)	(0.00494)
Regional unemployment rate				-0.04626	-0.02316
				(0.04525)	(0.04576)
Mining				-0.96303	-0.83165
				(0.16757)	(0.17980)
Construction				-0.48179	-0.33967
				(0.18568)	0.18607
Food,beverages, tobacco				0.47197	(0.36831)
				(0.24838)	0.27974
Textiles, leather, shoes				-0.35164	-(0.18404)
				(0.16558)	0.16666
Crafts (Wood)				-0.50785	-(0.30953)
				(0.30489)	0.30832
Paper, print, media				0.45128	(0.41790)
				(0.13798)	0.14968
Chemical, oil				0.14074	0.06014
				(0.23048)	(0.28179)
Metal manufacturing				0.39495	0.39177
				(0.17336)	(0.19324)

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Machine, automotive manufact.				0.34841	0.31438
				(0.21964)	(0.22799)
other manufacturing				0.10985	0.16147
				(0.22862)	(0.23905)
Hotel, restaurant				-0.60371	-0.49309
				(0.15048)	0.22618
Transport, communication				-0.63194	-(0.70244)
				(0.38179)	0.38360
Banking, insurance				0.46020	(0.29207)
				(0.22435)	0.23106
Real estate, IT, research				-0.00578	-(0.04896)
				(0.13182)	0.13921
Education				-0.16365	-(0.08172)
				(0.50798)	0.52169
Health, social institutions				-0.70462	-0.51993
				(0.20215)	(0.20744)
other services, culture, sport				-0.12779	-0.09082
				(0.27066)	(0.27331)
Administrative assistant					0.57526
					(0.10265)
Electrician					0.53191
					(0.15853)
IT specialist					0.85425
					0.16403
Polymechanics technician					(0.50894)
					0.20376
Sales clerk (3 years)					(0.18038)
					0.21148
Sales clerk (2 years)					(0.53512)
					0.22053
Cook					-(0.06404)
					0.23778
Year 2000 (1=yes/0=no)		-0.52388	-0.45493	-0.39233	-0.42539
		(0.09463)	(0.09497)	(0.10717)	(0.11130)
Constant	8.14941	8.29116	6.87026	7.17348	7.11716
	(0.10817)	(0.11949)	(0.21885)	(0.32883)	(0.32885)
R^2	0.005	0.028	0.054	0.095	0.114
Observations	4032	4032	4032	4032	4032

Robust standard errors in parentheses. The reference category is a firm in the mining industry and surveyed in the year 2004.

Chapter 2

Hiring Costs and Monopsonistic Labor Markets[1]

2.1 Introduction

Models of perfect competition in the labor market are based on the assumption that an individual firm faces a market wage at which any number of workers can be hired. In other words, the firm's labor supply curve is assumed to be infinitely elastic with respect to the wage. This implies that a firm trying to pay a wage below the market wage is not able to hire any workers at all. This assumption is rather extreme and inconsistent with the empirical evidence about the relation between the wage and the number of workers that quit a firm in a given time period.

In recent years, the idea that labor markets are characterized by monopsonistic aspects has become increasingly popular in the economic literature. In particular, the generalized model of monopsony introduced by Manning (2006) analyzes the labor market from the real-world perspective that firms set wages. It is based on the assumption that the wage elasticity of the labor supply to a firm is finite. This means that the firm can choose which wage to pay if it wants to keep employment at a certain level. If the firms decide to set a low wage, direct labor costs decrease. However, this will in turn increase the fluctuation rate, leading to higher hiring costs. Hence, in the generalized model

[1]This chapter is joint work with Marc Blatter and Samuel Muehlemann

of monopsony, the firms face a trade-off between direct and indirect labor costs. This is neither the case in the perfectly competitive model nor in the traditional monopsony model. In purely competitive models of the labor market, firms take wages as given. In the traditional monopsony model, the firms choose their optimal level of employment and have to pay a wage that is determined by the labor supply. Firms can only recruit more workers by raising the wage. They do not have the possibility to attract additional workers by increasing expenditures on hiring activities.

The generalized model of monopsony introduces a so-called labor cost function. It is defined as the firm's non-wage costs per worker to keep employment constant at a given level if the firm pays a given wage. According to the generalized model of monopsony, monopsony is characterized by a setting in which the labor cost function is increasing in employment. In order to directly test this implication empirically, data on both wages and the firm's hiring costs are needed. Due to the lack of wage information, the generalized model of monopsony could not be directly tested in Manning (2006). In this chapter we use the results from chapter 1, i.e. the parameters of the firm's hiring cost function, in order to test the monopsony hypothesis of the generalized model of monopsony.

Our empirical results support the monopsony condition provided by the generalized model of monopsony. We find that the firm's labor costs are increasing in the level of employment, which in turn fulfills the model's monopsony criterion. However, we point out that the generalized model of monopsony is based on a strong assumption, i.e. that labor costs decrease if the wage paid by the firm increases. But the effect of a wage increase on labor costs is twofold. On the one hand, a higher wage reduces the number of workers that leave the firm per period. But on the other hand, a higher wage increases the firm's hiring costs, since wages are an important component of hiring costs.

Finally, the empirical findings within the framework of the generalized model of monopsony are supported by estimations of wage equations. In theory, a monopsonistic labor market is characterized by firms being able to set wages. This is also what we find in our data.

The chapter is organized as follows. In the next section, we introduce the generalized model of monopsony. In section 2.3, we present our empirical analysis and section 2.4 concludes.

2.2 Theory

2.2.1 Related Literature

This chapter relates to the literature on monopsony in labor markets, surveyed by Boal and Ransom (1997). In particular, Burdett and Mortensen (1998) introduce a model in which workers receive and respond to information about alternative job offers while being employed. The model has different empirical implications which are consistent with labor market data, e.g., that there is a positive relation between the wage paid by a firm and job tenure. This implication is also confirmed by our data, since we find a negative relation between the wage and the percentage of workers that leave the firm per period. Bhaskar et al. (2002) argue that models of oligopsony or monopsonistic competition can explain many empirical observations in labor markets. Manning (2003) defines monopsony as a situation where the following two assumptions about the labor market hold. First, employers have some market power over their workers in the sense that a small wage cut does not induce them to leave the firm. Second, the employers exercise this market power and set wages. Manning (2006) introduces a generalized model of monopsony in which a firm can increase its workforce either by offering a higher wage or by increasing expenditures on recruitment activities. Using this model, he shows that monopsony corresponds to a situation in which there are increasing marginal costs of recruitment, which implies that the total labor costs of a firm are increasing in the level of employment. However, the British data set used in Manning (2006) does not contain data on wages. This makes it impossible to estimate hiring costs directly in order to test whether there are diseconomies of scale in recruitment. Since our firm-level data of Swiss firms contain information on wages, we can test the implications of the generalized model of monopsony directly.

2.2.2 The Generalized Model of Monopsony

In this section we present the generalized model of monopsony introduced by Manning (2006). The main feature of this model is that a firm can attract new workers both by offering a higher wage and by increasing its hiring activities. The costs to hire a new worker on the external labor market are denoted by $H(R, N, w)$. These costs depend firstly on the number of recruits R. Hiring costs can also depend on the number of skilled workers N that are already employed by the firm, since a large N may influence the recruitment process. In addition, firms with a large N might be more attractive because they provide better career opportunities, which would in turn make it easier for such firms to hire additional workers. The wage w has two countervailing effects on H. On the one hand, firms offering high wages are more attractive, hence more individuals will apply for vacancies. On the other hand, a higher wage makes training more costly, since a newly hired worker does not reach his full level of productivity immediately after he has been employed. During the initial period a firm has to pay a wage which is higher than the worker's effective productivity. The share of workers that leave the firm in a given time period is given by the separation rate $s(w)$. Hence, a firm needs to hire sN recruits per period in order to keep employment constant at N. In equilibrium, the non-wage labor costs per worker to maintain a constant employment level are given by $C(w, N) = H(R, N, w)s(w)$.

In the simple generalized model of monopsony, the only production factor is labor, the firm's revenue function is therefore $F(N)$. The firm maximizes profits which are given by

$$\pi = F(N) - [w + C(w, N)]N$$

Assuming that $C(w, N)$ is differentiable and $C_{ww} > 0$, this yields the first-order condition

$$C_w(w, N) = -1 \qquad (2.1)$$

In the generalized model of monopsony, the firm can choose which wage to pay if it wants to keep employment at a certain level N. However, the firm has to consider that a low wage w increases the fluctuation rate $s(w)$. Hence, the firm solves

$$\omega(N) = \min_w [w + C(w, N)]$$

Manning (2006) defines this expression as the *effective labor supply curve*. Profits are therefore given by $\pi = F(N) - \omega(N)N$. $\omega(N)$ replaces the traditional labor supply curve $w(N)$ in a standard model of monopsony. The difference is that the total labor costs $\omega(N)$ include both the wage and non-wage labor costs, i.e., the cost to hire workers, whereas in the standard monopsony model labor costs are given by the wage only. However, it is of some interest whether the *effective labor supply curve* $\omega(N)$ is increasing in N which would be the equivalent of an upward-sloping *labor supply curve*.

Applying the envelope theorem and using the first-order condition above (equation 2.1) yields

$$\omega'(N) = C_N[w(N), N] \tag{2.2}$$

As a result, the *effective labor supply curve* is upward sloping if non-wage labor costs C are increasing in N. In the following section, we will use our data described in section 1.3 to test exactly this hypothesis.

2.3 Empirical analysis

This section is divided into two parts. First, I discuss the empirical characteristics of the effective labor supply curve. The second part reports the results of the estimated wage functions.

2.3.1 Effective labor supply

Within the framework of the generalized model of monopsony, monopsony corresponds to the case where the non-wage labor costs to keep employment at a certain level, C, are increasing in N (see equation 2.2). In this section, we attempt to empirically test this hypothesis using the data described in chapter 1. Since non-wage labor costs C are not directly observed, we first estimate the parameters of the hiring costs H. Using these results, we second infer the parameters of C applying the relations provided by the generalized model of monopsony.

Assuming that employment N is constant in the steady state, the costs per worker to keep employment at this level are given by the non-wage labor cost function $C = sH$. It can be seen that the level of H is not the only determinant of C. Given the employment level N, the fluctuation rate s determines the number of recruits R that have to be hired in a given period, since $R = sN$.

For the non-wage labor cost function we assume the following iso-elastic form

$$C = w^{\delta} R^{\gamma_0} N^{\gamma_1}$$

Since $R = sN$ and $C = sH$ in the steady state, we get

$$\begin{aligned} sH &= w^{\delta} R^{\gamma_0} N^{\gamma_1} \\ \frac{R}{N} H &= w^{\delta} R^{\gamma_0} N^{\gamma_1} \\ &\Leftrightarrow \\ H &= w^{\delta} R^{\gamma_0 - 1} N^{\gamma_1 + 1} \end{aligned}$$

Taking logs yields the following regression equation

$$\ln H \equiv c + \delta \ln w + (\gamma_0 - 1) \ln R + (\gamma_1 + 1) \ln N$$

We already estimated this equation in chapter 1. Therefore, we can use the results from our preferred model (3) in Table 1.2 as an approximation for the steady state values of β_0 and β_1.[2] Now, we can infer the coefficients for γ_0 and γ_1, since

$$\begin{aligned} \gamma_0 &= \beta_0 + 1 = 1.089 \\ \gamma_1 &= \beta_1 - 1 = -0.999 \end{aligned}$$

In equilibrium $R = sN$, hence

$$C = w^{\delta} s^{\gamma_0} N^{\gamma_0 + \gamma_1}$$

Therefore, the elasticity of C with respect to N is $\gamma_0 + \gamma_1 = 0.099$. We can test whether $\gamma \equiv \gamma_0 + \gamma_1 = 0$. A Wald-Test of the hypothesis that $\gamma = 0$ is rejected with a p-value < 0.0001. This implies that an increase in the level

[2] The detailed estimation output including control variables is shown in Table 1.A8.

of skilled workers N by 10% increases the per-worker hiring costs C by 1%. While this effect is relatively small, it implies that the per-worker hiring costs are increasing in N.

As outlined in section 2.2.2, $C_N > 0$ implies $\omega'(N) > 0$. Hence, we can provide empirical evidence that is consistent with the predictions of the generalized model of monopsony. In contrast to the traditional simple model of monopsony, firms can increase their employment both by paying higher wages and by raising expenditures on recruitment activities. However, our results should be interpreted with some caution. The reason is that the effect of a wage increase on labor costs $C = s(w)H(w)$ is twofold. On the one hand, an increase in w reduces the separation rate $s(w)$, because workers are less likely to leave the firm at a higher wage level. We find an elasticity of the separation rate with respect to the wage of -0.4, which is substantial but not infinite as predicted by a competitive model of the labor market. On the other hand, a higher wage also increases $H(w)$, because wages are an important component of hiring costs, especially of adaption costs. Therefore, the assumption made in the generalized model of monopsony by Manning (2006), $C_w(w, N) = -1$ does not necessary need to be fulfilled.

2.3.2 Monopsonistic wage function

So far, the results in favor of a monopsonistic labor market are based on the *effective labor supply curve* generated by the generalized model of monopsony. A more general hypothesis to test for monopsony is the main feature of a monopsonistic labor market, i.e. that firms are able to set wages. This can be done by estimating wage functions. If the labor market is perfectly competitive, the average wage for same professions should not vary across firms.

We estimate a wage function with respect to firm size and hiring costs. To control for other variables that could influence the wage, we include control variables for different professions, economic sectors and macroeconomic environment. Throughout the different regression specifications we find a positive and strongly significant correlation between the wage and the firm size and the size of the hiring costs, respectively (see Table 2.1)[3]. Firm size

[3]The detailed estimation output including control variables is shown in Table 2.A1.

Table 2.1: Estimation of the wage function

Dependent variable:	Wage (w)			
	(1)	(2)	(3)	(4)
Hiring Costs	0.0014	0.0021	0.0018	
	(0.0001)	(0.0001)	(0.0001)	
Number of recruits R	-0.0386	-1.0434	-0.9463	
	(0.2940)	(0.5543)	(0.4947)	
Number of skilled workers N	0.2485	0.6290	0.6482	0.6936
	(0.0633)	(0.1362)	(0.1275)	(0.9829)
Employees other than N	0.0599	0.0367	0.0284	0.0551
	(0.0121)	(0.0315)	(0.0286)	(0.0270)
Aggregate regional income	0.0006	0.0006	0.0006	0.0008
	(0.0001)	(0.0001)	(.0001)	(.0002)
Regional unemployment rate	2.7955	6.9306	7.5045	6.8514
	(1.9979)	(1.7570)	(1.7064)	(1.7662)
Profession Controls	Yes	No	Yes	Yes
Industry Controls	No	Yes	Yes	Yes
R^2	0.2479	0.3038	0.3323	0.2477
Observations	4032	4032	4032	4032

Robust standard errors in parentheses. The reference category is a firm in the mining industry and surveyed in the year 2004.

is captured by the number of skilled workers N and the number of employees other than N. On average, in the preferred model (3) an increase in N of 10% leads to an increase in the wage of 6.5%. The effect of the number of employees other than N is positive as well, but smaller and less significant. The effect of the hiring costs on the wage is again strongly significant but relatively small, i.e. an increase of 10% in hiring costs increases the wage by around 0.02%. In other words, firms with high non-wage labor costs pay higher wages in order to discourage separations (since recruiting new workers is relatively costly). Summarizing, our results support the hypothesis that firms have some range for setting individual wages, which in turn is evidence against a perfectly competitive labor market.

2.4 Conclusions

In the generalized model of monopsony introduced by Manning (2006), firms can increase their number of workers both by offering a higher wage and by increasing their expenditures on hiring activities. In the framework of this model, monopsony corresponds to the case where the firm's costs per worker to keep employment constant at a given level are increasing in employment. We use Swiss establishment-level data to test the hypothesis whether the so-called labor cost function is in fact increasing in the level of employment. Our empirical results are consistent with this hypothesis. Furthermore, by estimating wage functions we find that firms are able to set wages. Firms with high non-wage labor costs pay higher wages in order to discourage separations. This again is evidence against a perfectly competitive labor market.

2.A Appendix

Table 2.A1: Estimations of the wage function

Dependent variable:	Wage (w)			
	(1)	(2)	(3)	(4)
Hiring Costs	0.0014	0.0021	0.0018	
	(0.0001)	(0.0001)	(0.0001)	
Number of recruits R	-0.0386	-1.0434	-0.9463	
	(0.2940)	(0.5543)	(0.4947)	
Number of skilled workers N	0.2485	0.6290	0.6482	0.6936
	(0.0633)	(0.1362)	(0.1275)	(0.9829)
Employees other than N	0.0599	0.0367	0.0284	0.0551
	(0.0121)	(0.0315)	(0.0286)	(0.0270)
Aggregate regional income	0.0006	0.0006	0.0006	0.0008
	(0.0001)	(0.0001)	(0.0001)	(0.0002)
Regional unemployment rate	2.7955	6.9306	7.5045	6.8514
	(1.9979)	(1.7570)	(1.7064)	(1.7662)
Mining		71.8107	62.5139	53.2531
		(4.6110)	(5.0029)	(5.2783)
Construction		27.2273	21.0222	12.6546
		(9.5416)	(8.6664)	(8.8164)
Food, beverages, tobacco		5.2592	-1.7101	2.2997
		(9.2070)	(10.6357)	(10.8456)
Textiles, leather, shoes		61.8787	52.2581	42.3592
		(8.8723)	(9.2863)	(9.5926)
Crafts (Wood)		74.1849	65.3340	64.1828
		(14.4936)	(14.6552)	(14.2786)
Paper, print media		43.8589	35.0022	47.0725
		(7.3179)	(7.4539)	(7.7441)
Chemical, oil		49.5459	39.7813	42.6734
		(6.8913)	(7.3500)	(7.7036)
Metal manufacturing		44.6901	36.5166	49.5269
		(8.0903)	(8.3507)	(8.1124)
Machine, automotive manufact.		39.3494	30.0285	44.4299
		(8.5883)	(8.6336)	(9.2766)
other manufacturing		34.7016	25.4548	20.6617
		(17.7483)	(17.7839)	(17.4123)
Hotel, restaurant		13.9359	18.8264	10.3380
		(5.7581)	(7.1304)	(7.3643)

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Transport, communication		46.5515	31.7665	24.3380
		(11.1808)	(10.5872)	(10.9241)
Banking, insurance		31.4138	18.5619	31.8780
		(10.8925)	(11.4187)	(12.1406)
Real estate, IT, research		49.6028	34.6322	38.6020
		(4.5897)	(4.8562)	(5.2673)
Education		17.4113	8.5063	12.7945
		(11.1749)	(10.9284)	(12.0189)
Health, social institutions		8.7411	0.5947	-8.0147
		(4.5997)	(4.8288)	(5.5819)
other services, culture, sport		2.9010	-7.6702	-8.6636
		(8.2373)	(8.2186)	(8.5982)
Administrative assistant	5.6482		10.6929	21.4531
	(2.7214)		(4.0411)	(4.3749)
Electrician	33.7701		-2.1698	1.6600
	(6.6789)		(10.1021)	(10.1440)
IT specialist	50.0374		43.9188	70.1004
	(5.9145)		(12.2989)	(12.2635)
Polymechanics technician	19.5249		2.9418	8.7590
	(5.2374)		(7.7751)	(8.1937)
Sales clerk (3 years)	-53.0606		-20.1134	-20.6243
	(6.9361)		(8.4217)	(8.8412)
Sales clerk (2 years)	-86.1857		-49.6848	-55.5744
	(7.4324)		(6.3217)	(6.2871)
Cook	-42.6165		-23.8716	-29.7006
	(5.6121)		(8.7113)	(9.1115)
Year 2000 (1=yes/0=no)	-21.5988	-22.5002	-20.7191	-21.5465
	(3.9022)	(3.9164)	(3.7950)	(3.9096)
Constant	301.3024	248.4289	256.8199	269.1676
	(6.0141)	(7.9647)	(7.6860)	(8.3125)
R^2	0.2479	0.3038	0.3323	0.2477
Observations	4032	4032	4032	4032

Robust standard errors in parentheses. The reference category is a firm in the mining industry and surveyed in the year 2004.

Chapter 3

Hiring Costs and the Firm's Supply of Training[1]

3.1 Introduction

To recruit skilled workers, firms incur substantial hiring costs. First, they have to post vacancies and process interviews with job-applicants. Second, it takes time for a newly hired worker to reach full productivity in the new job. In short, the firm's hiring costs include both recruitment and adaption costs. However, firms have the possibility to avoid such costs. Instead of hiring all workers on the external labor market, firms can train workers internally until they reach the desired skill level. There are many types of firm training, e.g., on- and off-the-job training, trainee programs, internships or apprenticeship programs.

The effect of hiring costs on the supply of training by firms can be applied to all the types of training mentioned above. However, to make our analysis more tractable, we focus on apprenticeship training, which is particularly widespread in Europe. In Germany and Switzerland, more than half of a cohort of school-leavers choose this type of education. Firms hire young people as apprentices after compulsory schooling. After completion of training, firms may retain them as skilled workers. Obviously, the decision to train apprentices also depends on the costs of training. Training apprentices might be a profitable strategy for a firm to satisfy its labor demand if the costs of training an apprentice are below

[1]This chapter is joint work with Marc Blatter Samuel Muehlemann

the costs of hiring a skilled worker on the external labor market. In this sense, the benefits of training apprentices include reduced marginal hiring costs for skilled workers, given that a firm is able to retain a former trainee as a skilled worker after training.

A standard assumption in a model of perfect competition in the labor market is that firms take wages for skilled workers as given. However, there is a large recent literature that provides evidence in favor of monopsonistic labor markets. We carry out our analysis in the framework of a generalized model of monopsony (see Manning (2006)), in which firms set wages. This has several implications. First, by offering a higher wage, firms can reduce labor turnover. Hence, a firm that offers higher wages has to recruit fewer workers to keep employment constant at a certain level. This also implies lower marginal hiring costs, since they depend positively on the number of recruited workers in a given time period. Second, if a firm offers a higher wage, it is more attractive to workers looking for a job. This in turn reduces hiring costs because the firm needs to spend less money to find an appropriate match. We extend the monopsony model such that firms can adjust their labor force not only by recruiting skilled workers on the external labor market, but also by training apprentices within the firm and retaining them as skilled workers after completion of training.

Our results show that an increase in hiring costs leads to a significantly higher supply of training positions by a firm. This is due to the fact that a firm can satisfy its demand for skilled workers by employing former trainees as skilled workers after training. Hence, a firm needs to recruit fewer skilled workers from the external labor market and can thereby avoid the corresponding hiring costs.

This chapter is organized as follows. First, we give a brief overview of the related literature. Section 3.3 outlines the theoretical model of the firm's supply of training. Section 3.4 provides some important facts about the vocational training system in Switzerland, which we use to illustrate the effects of hiring costs on the firm's supply of training. Section 3.5 describes the data. Section 3.6 contains the econometric modeling and the empirical results. Section 3.7 concludes.

3.2 Related Literature

Stevens (1994) provides an investment model for the supply of training, in which the employer's return is given by reduced recruitment costs for skilled workers. However, due to the lack of data on both hiring costs and net costs of training, Stevens has to make strong assumptions. For instance, wage data serve as a proxy for the training costs and a variable indicating a shortage of skilled labor is used as a proxy for hiring costs.

Our main interest is the effect of hiring costs on the firm's supply of training. The only studies known to the authors that use direct data on the firms' hiring costs are Manning (2006), Kramarz and Michaud (2004), and Abowd and Kramarz (2003). However, in the British data used by Manning (2006), hiring costs are only captured in intervals and not as exact values. The studies by Kramarz and Michaud (2004) and Abowd and Kramarz (2003) have the limitation that hiring costs do not contain the costs associated with the adaptation of newly hired workers, which may be a substantial part of hiring costs.

Other studies analyze the relation between the costs and the supply of training, but without considering hiring costs. Muehlemann et al. (2007) estimate the firm's supply of training using firm-level data with detailed costs of training. They find that expected costs are an important determinant of the firm's decision to train apprentices. Wolter et al. (2006) show that expected training costs are significantly higher for non-training firms than for firms that do offer training.

In contrast to the existing literature on firm-sponsored training, our detailed firm-level data contains information on both hiring and training costs. This allows us to estimate simultaneously the effects of training costs and hiring costs on the firm's supply of apprenticeships.

3.3 Model

The model of the labor market used in this section is an extended version of the generalized model of monopsony introduced by Manning (2006)[2]. In contrast to

[2]Chapter 2 introduces the static version of the generalized model of monopsony.

other models used in the literature on employment adjustment costs, the wage is no longer treated as exogenously given to the firm. $H(R, N, w)$ denotes the costs of recruiting and training a worker. First of all, these costs depend on the number of recruits R. At this point, we do not specify a functional form of H with respect to R. Instead, we allow the marginal hiring costs with respect to R to be increasing, constant or decreasing. Furthermore, H depends on the number of skilled workers N that are already employed by the firm because large firms might have a more sophisticated recruitment process. It is also possible that firms with a large N offer more attractive career opportunities, enhancing the ability of such firms to hire workers. The number of skilled workers N can be increased by either recruiting skilled workers R on the labor market or by employing trainees L after their training period.

The wage w has two effects on H. Firms offering high wages are more attractive, hence more workers will apply to vacancies. However, a higher w also makes hiring more costly, since a worker does not reach his full level of productivity in the initial period after he has been hired. During this adaption period, a firm has to pay w, which is higher than the worker's productivity.

The costs of a trainee are denoted by $C(L)$. These costs are defined as net of the trainee's output contribution and independent of the number of skilled workers. Furthermore, we assume that the costs of training outweigh the trainee's output contribution during the training period. Therefore, skilled labor is the only production factor in our model.

The firm maximizes the present discounted value of its profits

$$\max_{R_t, w_t, L_t} \Pi = \sum_{t=0}^{\infty} \beta^t \left[F(N_t) - w_t N_t - H(R_t, N_t, w_t)R_t - C(L_t)L_t\right]$$

subject to the constraint

$$N_{t+1} = (1 - \delta(w_t))N_t + R_t + (1 - \gamma(w_t))L_t$$

where $F(N_t)$ denotes the firm's revenue function, $\delta(w)$ is the separation rate, i.e., the percentage of skilled workers that leaves the firm per period, with $0 \leq \delta(w) \leq 1$.[3] $\gamma(w)$ denotes the fraction of trainees which leave the firm after

[3] The separation rate is assumed to be continuous in the wage. We can in fact test this

having completed their training, with $0 \leq \gamma(w) \leq 1$. The remainder, $(1-\gamma(w))$, turns into skilled labor and stays in the firm.

We solve the problem of the firm by applying dynamic programming. Hence, we define the value function $V(N)$ to be the discounted value of profits if the employer has employment equal to N. The maximization problem in the Bellman form can then be written as:

$$V(N_t) = \max_{R_t, w_t, L_t} F(N_t) - w_t N_t - H(R_t, N_t, w_t)R_t - C(L_t)L_t + \beta V(N_{t+1}) \tag{3.1}$$

subject to the constraint

$$N_{t+1} = (1 - \delta(w_t))N_t + R_t + (1 - \gamma(w_t))L_t \tag{3.2}$$

where $\beta = \frac{1}{1+r}$ is the discount factor. Substituting (3.2) into (3.1) gives

$$V(N_t) = \max_{R_t, w_t, L_t} F(N_t) - w_t N_t - H(R_t, N_t, w_t)R_t - C(L_t)L_t + \beta V((1 - \delta(w_t))N_t + R_t + (1 - \gamma(w_t))L_t)$$

Taking the first-order condition with respect to R_t yields

$$- H - R_t H_{R_t} + \beta V'(N_{t+1}) = 0 \tag{3.3}$$

The first-order condition with respect to w_t can be written as

$$- N_t - H_{w_t} R_t - \beta V'(N_{t+1})(\delta'(w_t)N_t + \gamma'(w_t)L_t) = 0 \tag{3.4}$$

The first-order condition with respect to L_t can be written as

$$- C_{L_t} L_t - C + \beta V'(N_{t+1})(1 - \gamma(w_t)) = 0 \tag{3.5}$$

To get a further optimality condition it is common to apply the Envelope Theorem in the Bellman context. In our case this is the derivative of the value function with respect to N_t:

$$V'(N_t) = F'(N_t) - w_t - H_{N_t} R_t + \beta V'(N_{t+1})(1 - \delta(w_t)) \tag{3.6}$$

assumption and find an elasticity of -0.4, i.e., a 10% increase in the wage leads to a 4% decrease in the separation rate. This indicates that the firm can reduce the separation rate by paying a higher wage.

In the steady state wages and employment are constant. This implies that we can rewrite (3.6) and solve for $V'(N)$:

$$V'(N) = F'(N) - w - H_N R + \beta V'(N)(1 - \delta(w)) \tag{3.7}$$

$$\Rightarrow \quad V'(N) = \left(\frac{1+r}{r+\delta(w)}\right)(F'(N) - w - H_N R) \tag{3.8}$$

Using steady state terms and the Envelope Theorem, condition (3.3) yields

$$H + RH_R = \beta V'(N) \tag{3.9}$$

$$\Rightarrow \quad H + RH_R = \left(\frac{1}{r+\delta(w)}\right)(F'(N) - w - H_N R) \tag{3.10}$$

Using steady state terms and the Envelope Theorem, condition (3.4) yields

$$-N - H_w R = \beta\left(\frac{1+r}{r+\delta(w)}\right)(F'(N) - w - H_N R)\left(\delta'(w)N + \gamma'(w)L\right) \tag{3.11}$$

which combined with (3.10) yields

$$-N - H_w R = (H + RH_R)(\delta'(w)N + \gamma'(w)L) \tag{3.12}$$

Using steady state terms and the Envelope Theorem, condition (3.5) yields

$$C_L L + C(L) = \beta\left(\frac{1+r}{r+\delta(w)}\right)(F'(N) - w - H_N R)(1 - \gamma(w)) \tag{3.13}$$

which combined with (3.10) yields

$$C_L L + C(L) = (H + RH_R)(1 - \gamma(w)) \tag{3.14}$$

Rearranging terms, (3.12) yields

$$H + RH_R = \frac{-(N + H_w R)}{(\delta'(w)N + \gamma'(w)L)} \tag{3.15}$$

which we combine with (3.14) to get

$$C_L L + C(L) = \frac{-(N + H_w R)}{(\delta'(w)N + \gamma'(w)L)}(1 - \gamma(w)) \tag{3.16}$$

So far we used a very general framework. Next, we assume more specific functions to learn more about the comparative statics in this model's steady state.

$$C(L_t) = c_t L_t \tag{3.17}$$

$$H(R_t, w_t, N_t) = w^{\alpha} R^{\beta} N^{\gamma} \tag{3.18}$$

$$\delta(w_t) = 1 - \xi w_t \tag{3.19}$$

$$\gamma(w_t) = 1 - \epsilon w_t \tag{3.20}$$

We assume a linear form of the training cost function C. The iso-elastic functional form of hiring costs is proposed by Manning (2006). The coefficients α, β and γ are exogenously given to an individual firm. The functional forms of the separation rates reflect the negative relation between the wage and the separation rates. Higher wages make it less attractive for workers to switch jobs.

With this functions, equation (3.16) can be written as

$$cL + cL = \frac{-(N + \alpha w^{\alpha-1} R^{\beta} N^{\gamma} R)}{(-\xi N - \epsilon L)} \epsilon w \tag{3.21}$$

Rearranging terms, we can rewrite this equation to get a quadratic solution for L

$$\begin{aligned}
& -(\xi N + \epsilon L) 2cL = -(N + \alpha w^{\alpha-1} R^{\beta+1} N^{\gamma}) \epsilon w \\
\Rightarrow \quad & (2\xi N c L + 2\epsilon c L^2) = (N + \alpha w^{\alpha-1} R^{\beta+1} N^{\gamma}) \epsilon w \\
\Rightarrow \quad & 2\epsilon c L^2 + 2\xi N c L - (N + \alpha w^{\alpha-1} R^{\beta+1} N^{\gamma}) \epsilon w = 0
\end{aligned}$$

Solving this quadratic equation yields

$$L_{1,2} = \frac{-2\xi N c \pm \sqrt{4\xi^2 N^2 c^2 + (8\epsilon c(N + \alpha w^{\alpha-1} R^{\beta+1} N^{\gamma}) \epsilon w)}}{4\epsilon c}$$

Since we can not have a negative supply of training by a firm, there is obviously only one solution which makes sense:

$$L = \frac{-2\xi N c + \sqrt{4\xi^2 N^2 c^2 + (8\epsilon^2 c(N + \alpha w^{\alpha-1} R^{\beta+1} N^{\gamma}) w)}}{4\epsilon c} \tag{3.22}$$

To get a non-negative expression for L, we infer that

$$\sqrt{4\xi^2 N^2 c^2 + (8\epsilon^2 c(N + \alpha w^{\alpha-1} R^{\beta+1} N^{\gamma}) w)} \geq 2\xi N c$$

This is the case if

$$\left(8\epsilon^2 c(N + \alpha w^{\alpha-1} R^{\beta+1} N^{\gamma})w\right) \geq 0$$

or if

$$N \geq -\alpha w^{\alpha-1} R^{\beta+1} N^{\gamma}$$

This condition can be rewritten as

$$wN \geq -\alpha RH$$

If α is positive, this condition obviously holds. The condition is also fulfilled for negative values of α, if α is not unreasonably large in absolute values or if total wage costs wN are substantially higher than total hiring costs RH in a given period.

To sum up, we derived the firm's supply function of training positions, which is given by equation (3.22). Since we are interested in the effect of hiring costs H on the number of trainees L, we rewrite equation (3.22) as

$$L = \frac{-2\xi Nc + \sqrt{4\xi^2 N^2 c^2 + 8\epsilon^2 c(wN + \alpha RH)}}{4\epsilon c} \tag{3.23}$$

This expression indicates a positive relation between hiring costs H and the firm's supply of training positions L. This means that firms facing high hiring costs decide to offer training positions in order to cover part of their demand for skilled workers, instead of only recruiting skilled workers on the external labor market.

3.4 The apprenticeship system

The apprenticeship system has a long tradition in German speaking countries. It is characterized by the so-called dual education system, i.e., a training program combining training and working within a firm and vocational education at school. In Switzerland, this path is chosen by around 60% of young people who complete their compulsory schooling. From the remaining 40%, about one half attend grammar school to prepare them for an academic education whereas the remainder opt either for other entirely school-based forms of education or pursue no form of post-compulsory education. Apprentices can choose from over 200 different professions. Usually, an apprenticeship training program lasts three to four years. During this program, an apprentice spends about one or two days per week in a public vocational school. During the rest of the week, an apprentice participates in the production process or receives further training within the firm. After having completed the training program, apprentices receive a diploma recognized throughout the country. Graduated apprentices who have acquired an additional qualification (professional baccalaureate), have access to third-level studies at a university of applied sciences. Hence, an individual with a completed apprenticeship has various perspectives for further professional development.

In 2004, Swiss firms offering apprenticeships invested 4.7 billion Swiss francs in their training programs, which corresponds to about 1% of GDP. The apprentices generate a value of 5.2 billion Swiss francs during the training program (Muehlemann et al. 2007a). Hence, an apprenticeship training program is profitable for the firm on average. However, approximately one third of the apprenticeships end with net costs for the firm. If the employer and the apprentice want to continue their employment relationship after the training program, they have to negotiate a new labor contract. In Switzerland, only 37% of apprentices remain within the firm where they received their training one year after graduation. By continuing the employment relation with the graduated apprentices, the firm can reduce its recruitment costs for skilled labor. This way, firms may offset some training costs against the costs of hiring skilled workers on the external labor market.

3.5 Data

The data used in this study are the same as presented in chapter (1). For a detailed description of the survey and of the calculation of hiring costs see section 1.3.

3.5.1 Calculation of the net costs of training apprentices

The net costs of apprenticeship training are given by the difference between the costs and benefits for the firm. The observed costs were calculated as follows: training costs are the wages of apprentices w_a and the cost for the training personnel w_T, which add up in equal shares to about 90 percent of total costs c. The remaining 10 percent are costs for material, infrastructure, external courses, hiring and administration of apprentices and other, x. This yields the following average costs for firm i:

$$c_i = w_{ai} + w_{Ti} + x_i$$

The survey data suggest that training costs consist mainly of wages. Hence, training cost differences between firms are primarily due to variables that influence the wage level of either apprentices or training personnel. The wages of apprentices are more or less predetermined by wage recommendations of professional associations. Thus, the variation of wages within a profession is relatively small, and a substantial part can be explained by a firm's size. Larger firms offer higher wages to apprentices, which is consistent with the fact that larger firms offer higher wages to all categories of workers. Similarly to standard wage regressions, the average wages of the trainers can be best explained using variables such as firm size, industry and regional characteristics. The remaining costs for material, infrastructure and external courses are essentially given by the training profession.

The benefits b are calculated by the type of work the apprentices perform. An apprentice spends a fraction α of his work hours performing activities that would otherwise be done by unskilled workers. The remaining time $(1-\alpha)$ the apprentice carries out activities of a skilled worker. While we can assume in the first case that the apprentice's performance has the same value as that of an unskilled worker (w_u), the value of the apprentice's performance for the second case, ςw, is compared to that of a fully trained skilled worker, where w is the wage paid to a skilled worker.

$$b_i = \alpha w_{ui} + (1-\alpha)\varsigma w_i$$

Much of the variation in the benefits of apprenticeship training can be explained with the determinants of both the apprentices' wages and the wages of skilled workers, as well as the profession in which an apprentice is trained.

The net costs of training an apprentice, C, are the difference between the costs c and the benefits b:

$$C_i = c_i - b_i$$

3.5.2 Descriptive Statistics

Table 3.A1 in the appendix reports the descriptive statistics. The number of apprentices L hired by firms is on average 0.9. The reason for such a low average supply of training positions is that only about one third of the firms train apprentices. But there is considerable variation in L. The highest number of apprentices trained by a firm is 134. The hiring costs H to fill a vacancy are between CHF 320 and CHF 17,0575 with a mean of CHF 14,285. The net costs of training apprentices C are on average CHF -8,119, which means that training is profitable from the firms' perspective already at the end of the training period. However, about one third of the firms have to bear net costs of training. The separation rate of apprentices γ, i.e., the fraction of trained apprentices that leave the firm within the first year after completion of training, is on average 64%. The number of recruited skilled workers over the last three years R within a profession is 2.8 on average.[4] The firms' overall demand for skilled workers P is 3.2 on average, which is higher than R because it includes the apprentices that a firm retains as skilled workers after completion of training. The monthly salary of skilled workers is on average CHF 6,423.[5] The number of skilled workers N is 6.7 on average, whereas the mean of employees other than N is 14.3.

3.6 Econometric model and empirical analysis

In this section we estimate the effect of hiring costs on the supply of training positions. Since firms supplying training may have reduced recruitment costs

[4]Firms that train apprentices had to report training costs and hiring costs for the same profession. Firms that do not train apprentices were asked to report hiring costs for the profession in which they would train apprentices if they decided to do so.

[5]It should be noted that w in the theoretical model refers to the wage over a period of three years.

for skilled labor, we cannot observe their potential hiring costs. Hence, we need to estimate these unobservable costs. In order to estimate the effect of hiring costs on the firm's supply of training, we need to control for the net costs of training. However, these costs can only be observed for firms that offer training. The expected net costs for non-training firms have to be estimated.

To overcome the selection problems, we use a type IV Tobit model, which is described in the next subsection.[6][7]

3.6.1 Type IV Tobit model

Consider the (structural) model of the firm's supply of training positions.

$$\ln H = x_1\beta_1 + \varepsilon_1 \tag{3.24}$$

$$C = x_2\beta_2 + \varepsilon_2 \tag{3.25}$$

$$L = \max[0, x_3\beta_3 + \alpha \ln H + \delta C + \varepsilon_3] \tag{3.26}$$

where again L denotes the number of trainees, H the costs of hiring skilled workers and C the net costs of training.

(x, L) is always observed; H is observed if $L = 0$, whereas C is observed if $L > 0$. $(\varepsilon_1, \varepsilon_2, \varepsilon_3)$ are independent of x with a zero-mean trivariate normal distribution. Furthermore, x_1 needs to contain at least one element that is not in x_3 and has a non-zero coefficient. In this case we use the binary variable *Difficulties to find skilled workers*. This variable is a measure of the tightness of the labor market.[8] If skilled labor is scarce, firms have to spend more resources on finding appropriate workers. This increases the hiring costs of the firm. However, we assume that a firm's difficulties of finding skilled workers has no direct impact on the supply of training positions. Similarly, x_2 contains at least one element that is not in x_3 and has a non-zero coefficient. In this case we use the variable *Local share of young people*. This variable measures the share of the

[6] For a classification of different types of Tobit models see Amemiya (1985).

[7] Firms that did not hire externally and did not offer training ($L = 0$ and $R = 0$) have been excluded from the sample because they do not provide any relevant information.

[8] See Majumdar (2007) for an analysis of the effect of labor market conditions on the firm's incentive to offer training.

15-19 years old people of the total population in a region.[9] The share of young people influences the net costs of training for the following reason. If there are many potential trainees for a firm, the probability of a firm to find a good match increases. This in turn reduces the firm's time and effort associated with training. However, we assume that the share of young people does not directly affect the firm's supply of training positions.

The coefficients of interest are the structural parameters α and δ. For identification, we follow the procedure described in Wooldridge 2002, pp.571. The reduced form for equation (5.3) is

$$\begin{aligned} L &= \max[0, x_3\beta_3 + \alpha(x_1\beta_1 + \varepsilon_1) + \delta(x_2\beta_2 + \varepsilon_2) + \varepsilon_3] \\ &= \max[0, x\rho_3 + \alpha\varepsilon_1 + \delta\varepsilon_2 + \varepsilon_3] \\ &= \max[0, x\rho_3 + u_3] \end{aligned} \tag{3.27}$$

In a first step we regress L on x by standard Tobit using all observations. This enables us to generate a generalized residual (see Vella 1992, p.418):

$$\hat{u}_{3i} = -\hat{\sigma}_3(1 - I_i)\phi(x_{3i}\hat{\beta}_3/\hat{\sigma}_3)(1 - \Phi(x_{3i}\hat{\beta}_3/\hat{\sigma}_3))^{-1} + I_i(L_i - x_{3i}\hat{\beta}_3)$$

where I_i is an indicator function denoting whether a firm offers training. A consistent estimate of u_{3i} is necessary to obtain estimates of β_1 and β_2, since

$$E(\ln H|L = 0, x, u_3) = x_1'\beta_1 + E(\varepsilon_1|x, u_3) = x_1'\beta_1 + E(\varepsilon_1|u_3) = x_1'\beta_1 + \gamma_1 u_3$$

and

$$E(C|L > 0, x, u_3) = x_2'\beta_2 + E(\varepsilon_2|x, u_3) = x_2'\beta_2 + E(\varepsilon_2|u_3) = x_2'\beta_2 + \gamma_2 u_3$$

where $u_3 = \alpha\varepsilon_1 + \delta\varepsilon_2 + \varepsilon_3$. The coefficients γ_1 and γ_2 can be used to test for selectivity (see also Vella 1992).

Using observations for which $L > 0$, we estimate the OLS regression

$$\ln H_i \quad \text{on} \quad x_{i1}, \hat{u}_{3i} \tag{3.28}$$

This yields consistent estimates of β_1 and allows to test for selectivity bias. Similarly, using observations for which $L = 0$, we estimate the OLS regression

$$C_i \quad \text{on} \quad x_{i2}, \hat{u}_{3i} \tag{3.29}$$

[9] A region is defined to contain all cities that can be reached by car within 30 minutes from a certain city.

This yields consistent estimates of β_2 and again allows to test for selectivity bias.

Now we have consistent estimates $\hat{\beta}_1$, $\hat{\beta}_2$ for β_1, β_2. This enables us to estimate β_3, α and δ using the following reduced form of L in terms of the structural parameters:

$$L = \max[0, x_3\beta_3 + \alpha \ln(x_1\beta_1) + \delta(x_2\beta_2) + u_3]$$

Using our consistent estimates $\hat{\beta}_1$, $\hat{\beta}_2$ we can estimate the following Tobit equation to obtain consistent estimates $\hat{\beta}_3$, $\hat{\alpha}$ and $\hat{\delta}$, which is what we are interested in:

$$L = \max[0, x_3\beta_3 + \alpha \ln(x_1\hat{\beta}_1) + \delta(x_2\hat{\beta}_2) + error_i] \tag{3.30}$$

It should be noted that the explanatory variables in equation (3.30) are $x_1\hat{\beta}_1$ and $x_2\hat{\beta}_2$ for all i and do not depend on $\hat{u}_{3i}$ in equations (3.28) and (3.29).

3.6.2 Results

First, we calculate the generalized residual by estimating equation (3.27).[10] Second, we estimate equation (3.28), i.e., we regress hiring costs $\ln H$ on x_1 and the generalized residual. The results are reported in Table 3.A3. Using only observations for which the potential hiring costs are observable (and therefore $L = 0$), we find that the firm's total demand for skilled workers $\ln P = \ln[R + (1-\gamma)L]$[11] has a positive and significant effect on hiring costs with an elasticity of 0.161.

As an exclusion restriction, i.e., a variable that has an effect on H but not directly on L, we included a dummy variable measuring the difficulties of a particular firm to find skilled workers on the external labor market. As expected, firms facing such difficulties exhibit about 23% higher hiring costs.

The coefficient on the generalized residual is not significantly different from zero. Hence, there does not seem to be a selection problem, i.e., the potential hiring costs of firms with $L > 0$ do not differ significantly from firms with $L = 0$.[12]

[10] The results of the reduced form equation are presented in Table 3.A2.

[11] Note that in this case $P = R$, since $L = 0$, i.e., the firm does not offer training.

[12] However, for reasons of consistency we include the generalized residual because there is a selection bias with regards to the net costs of training C (see Table 3.A4).

Furthermore, the firm size has a positive effect on H, although the number of skilled workers N is not significant alone.[13]

Next, we estimate equation (3.29), i.e., we regress the net costs of training C on x_2 and the generalized residual.

The estimation results are presented in Table 3.A4. The exclusion restriction used here is the share of young people in the population in a region. The results show that a 1%-point increase in the share of young people leads to a decrease in the net costs of training of CHF 3761. The intuition for this result is that firms are more likely to find a good match if the supply of young people is high. Therefore, they can save on training costs compared to firms that cannot find suitable trainees.

The coefficient on the generalized residual is now negative and significantly different from zero. This leads to the conclusion that the expected net costs of training for firms with $L = 0$ are significantly higher than those for firms with $L > 0$, indicating a sample selection problem. This confirms earlier findings of Wolter et al. (2006) and Muehlemann et al. (2007). In addition, the firm size has a positive effect on C. The number of skilled workers N and employees other than N are jointly significant at the 1%-level.

As a final step, we estimate the structural effects of H and C on the firm's supply of training positions L. The results show that both variables have a significant effect (see Table 3.1). Hiring costs of skilled workers have a positive effect on L. If H increases by CHF 1000, L increases by 0.25, implying that an increase in average hiring costs of CHF 4,000 induces a firm to hire an additional trainee. This effect is economically substantial, since an increase of H by one standard deviation leads to an increase of 3.5 training positions offered by a firm.

As expected, the net costs of training have a negative effect on the firm's supply of training. If the net costs C increase by CHF 1000, L decreases by 0.18. Similarly, an increase in C by one standard deviation leads to a decrease of 7 training positions on average.

Furthermore, the number of skilled workers and the number of other employees within the firm both have a positive effect on L. The wage of skilled workers w

[13] A Wald test for joint significance for total firm size (N + employees other than N) yields a p-value of 0.02.

Table 3.1: Supply of training positions

Dependent variable: L	
$\hat{H}$ (in 1000)	0.2497
	(0.0323)
$\hat{C}$ (in 1000)	-0.1837
	(0.0636)
P	-0.0188
	(0.0158)
N	0.0410
	(0.0064)
Employees other than N	0.0125
	(0.0022)
w	-0.0010
	(0.0002)
Foreign firm ownership	-1.1907
	(0.5231)
Aggregate cantonal income (in 1'000 CHF)	0.0064
	(0.0170)
Industry controls	Yes
Job controls	Yes
Log pseudolikelihood	-296125
Observations	4511

Cluster-robust standard errors in parentheses.

Table 3.2: Supply of training positions, $\hat{C} > 0$

Dependent variable: L	
$\hat{H}$ (in 1000)	0.4006
	(0.0730)
$\hat{C}$ (in 1000)	-0.2106
	(0.2216)
P	0.1604
	(0.0532)
N	0.0132
	(0.0078)
Employees other than N	0.0093
	(0.0039)
w	-0.0014
	(0.0004)
Foreign firm ownership	-1.2766
	(1.2605)
Aggregate cantonal income (in 1'000)	-0.0079
	(0.0457)
Industry controls	Yes
Job controls	Yes
Log pseudolikelihood	-67400
Observations	1331

Cluster-robust standard errors in parentheses.

has a negative effect on L. A possible explanation is that the wage is negatively related to the separation rate of trainees. Hence, a firms needs to train less apprentices in order to fill a given number of vacancies. Finally, foreign-owned firms have a significantly lower supply of training. This confirms the results of earlier studies. A possible explanation for this result is that such firms might be less familiar with the vocational training system or too specialized to provide a complete training program.

We have also estimated the supply of training positions using only firms with positive net costs C. Since the firm's total demand for skilled workers P depends on L by construction, because $P = R+(1-\gamma)L$, and β_P is significantly different from zero (which was not the case in the regression considering all $C's$), the coefficients in the regression output cannot be interpreted directly. Hence, we rewrite

$$\begin{aligned} L &= \beta_C C + \beta_H H + \beta_P P + \beta_X X + \beta_{[HC]} HC + u \\ &= \beta_C C + \beta_H H + \beta_P (R + (1-\gamma)L) + \beta_X X + \beta_{[HC]} HC + u \\ &\Leftrightarrow \\ L &= \frac{1}{1-\beta_P(1-\gamma)} \big(\beta_C C + \beta_H H + \beta_P R + \beta_X X + \beta_{[HC]} HC + u \big) \end{aligned}$$

Using this transformation, we find that an increase in hiring costs H of CHF 1000 yields an increase in the supply of training positions L of 0.425. Put differently, an increase in H by one standard deviation leads to an increase of 6 training positions supplied by the firm. The effect of H is stronger if we only consider firms with $C > 0$, because hiring costs are not the deciding factor if the firm does not need to recover any training investments after the training period.

Summarizing, the empirical results show that firms facing high hiring costs decide to offer more training in order to satisfy their demand for skilled workers compared to firms with low hiring costs.

3.7 Conclusions

Firm-sponsored training provides an alternative way to recruit skilled workers and allows firms to avoid high hiring costs. Our empirical results provide evidence that the firm's supply of training in fact depends on the firm's level of hiring costs. We find that an increase in average hiring costs has a substantial positive impact on the firm's supply of training positions. An increase in hiring costs by one standard deviation leads a firm to offer 6 additional training positions. This is an explanation for the well-known observation that firms are frequently willing to bear substantial training costs. Especially in times of shortages in skilled labor, when hiring costs are particularly high, it is beneficial for firms to supply training positions and retain their former trainees as skilled workers after training. A possible implication of our results is that firms are more willing to offer training positions if labor markets are strongly regulated. For example, a high degree of employment protection legislation forces firms to invest more in their hiring activities in order to avoid costly mismatches. Hence, training young workers internally may become an appropriate strategy for a firm to satisfy its demand for skilled workers.

3.A Appendix

Table 3.A1: Descriptive statistics

	Mean	Std. Dev.	Min	Max	Obs
Number of trainees L	0.904	2.351	0	134	4511
Hiring costs H	14284.710	14560.850	320	170575	1675
Net costs of training C	-8118.541	35048.480	-132707	149155	2836
Separation rate of trainees γ	63.771	34.470	0	100	2836
Number of recruits R	2.815	8.283	0	450	4511
Demand for skilled workers P	3.245	7.748	1	461	4511
Wage of skilled workers (per month)	6423.296	1450.822	2300	14430	4511
Number of skilled workers N	6.743	24.153	1	2400	4511
Number of employees other than N	14.318	74.916	0	4610	4511
Foreign-owned firm	0.120		0	1	4511
Construction sector	0.128		0	1	4511
Industrial sector	0.134		0	1	4511
Service sector	0.738		0	1	4511
Aggregate cantonal income	48949.400	10310.320	33699	82415	4511
Professional dummies:					
Administrative assistant	0.226		0	1	4511
Electrician	0.028		0	1	4511
Polymechanics technician	0.022		0	1	4511
Sales clerk	0.044		0	1	4511
Cook	0.061		0	1	4511
Local share of young people	0.057	0.005	0.047	0.071	4511
Difficulties to find skilled workers	0.395		0	1	4511
Year of survey (1=2000, 0=2004)	0.481		0	1	4511

Table 3.A2: Reduced form Tobit

Dependent variable: L	
P	0.0247
	(0.0169)
N	0.0432
	(0.0069)
Employees other than N	0.0112
	(0.0019)
w	-0.0001
	(0.0001)
Foreign firm ownership	-1.8638
	(0.2874)
Aggregate cantonal income (in 1'000 CHF)	-0.0073
	(0.0101)
Local share of young workers	69.4752
	(18.5540)
Difficulties to find skilled workers	0.8624
	(0.1771)
Industry controls	Yes
Job controls	Yes
Log pseudolikelihood	-298284
Observations	4511

Cluster-robust standard errors in parentheses.

Table 3.A3: Hiring costs regression

Dependent variable: $\ln H$	
$\ln P$	0.1611
	(0.0715)
$\ln N$	0.0166
	(0.0529)
ln(Employees other than N)	0.0209
	(0.0067)
$\ln w$	1.4741
	(0.1214)
Foreign firm ownership	0.0129
	(0.0795)
Aggregate cantonal income (in 1'000 CHF)	0.0052
	(0.0024)
Difficulties to find skilled workers	0.2332
	(0.0565)
Generalized residual	0.0098
	(0.0293)
Industry controls	Yes
Job controls	Yes
R^2	0.2676
Observations	1675

Cluster-robust standard errors in parentheses.

Table 3.A4: Net costs regression

Dependent variable: C	
P	-123.4067
	(41.8482)
N	22.4124
	(15.5346)
Employees other than N	17.7061
	(5.3174)
Foreign firm ownership	4755.4220
	(3831.6810)
Aggregate cantonal income (in 1'000 CHF)	171.9899
	(87.4384)
Local share of young workers (in %)	-3761.7190
	(1551.0780)
Generalized residual	-824.8130
	(257.2791)
Industry controls	Yes
Job controls	Yes
R^2	0.0886
Observations	2836

Cluster-robust standard errors in parentheses.

Introduction Part II

Real exchange rate theory and determination has a long tradition in economic literature. A good survey is provided in Taylor (1995). This second part of the thesis reconsiders two important aspects of real exchange rate theory. First, it assesses the importance of tradable and nontradable goods in explaining real exchange rate fluctuations. Second, it provides empirical evidence in favor of Purchasing Power Parity.

Chapter 4 analyzes real exchange rate fluctuations with respect to the role of tradable and nontradable goods. Traded goods can be exchanged across countries at relatively small transportation costs. Therefore, by traditional theory, the law of one price is assumed to hold for these tradable goods. In contrast, nontradable goods can not be exchanged and their prices are determined by domestic factors only. This leads to the conclusion that movements in the real exchange rate should primarily be determined by the relative price changes between tradable and nontradable goods within countries. But this theory is discussed controversially in the literature. It is a classic question in macroeconomics whether movements in the real exchange rate are mainly outcomes of fluctuations in the prices of tradable goods across countries or due to relative price changes of tradable compared to nontradable goods. Applying Engel's (1999) approach of variance decomposition, this study examines the composition of Switzerland's real exchange rate fluctuations. The results of this approach depend critically on how prices of goods are measured, particularly on the measurement of tradable and nontradable goods prices. Therefore two different indicators are used to determine these price levels. The first one is a combination of export and import price indices, the second one is the producer price index. However, the main finding of this study is that relative price changes between tradable and nontradable goods are important in explaining real exchange rate movements. Using import and export indices as a measure of tradable goods prices, these relative price changes between tradable and nontradable goods actually account for more than 50 percent of real exchange rate movements.

Chapter 5 examines real exchange rate movements from a monetary point of view. Particulary, the focus lies on the concept of Purchasing Power Parity (PPP). PPP is one of the oldest principle in explaining exchange rate movements in the long run. It is a necessary assumption underlying the monetary approach to real exchange rates. Here, the long run equilibrium exchange rate between two countries is determined primarily by their relative money supply and demand, transmitted through prices. The monetary approach adopted the quantity theory of money and PPP to explain the linkage between money and exchange rates. The quantity theory states that the price level depends on the demand adjusted money stock, i.e. that the price level equates supply and demand of money. The theory of PPP is based on the assumption that given free and frictionless markets, price differences across countries are cleared by arbitrage trades. In other words, in a monetary framework the quantity theory of money combined with the assumption of PPP determine the long run equilibrium exchange rate between two countries.

Convincing as the theory of PPP may be, finding empirical evidence proves difficult. Even though numerous studies show mean reversion in the very long run, the speed of convergence to PPP is very slow; deviations appear to damp out at a rate of 15 percent per year only (see Rogoff (1996)). Most of these studies assume a linear model and test for unit roots in real exchange rate time series. Even though the idea of nonlinear adjustment in real exchange rates first appeared in Heckscher (1916) it became widespread only in recent literature. Adjustment may not be linear because of transportation costs in international arbitrage trade. In other words, arbitrage trade does not take place until a certain threshold of price deviations is passed. However, by applying nonlinear estimation techniques, I show in chapter 5 that PPP holds with significantly faster speed of mean reversion than is found in other studies. The results are used in a second step to estimate monetary, multivariate real exchange rate models. Theses results imply a much stronger relationship between fundamental variables and the real exchange rate than is commonly believed, especially if the fluctuations in the real exchange rate exceed certain thresholds.

Chapter 4

Real Exchange Rates Fluctuations: The role of tradable and nontradable goods

4.1 Introduction

A common approach to determining the real exchange rate is to classify all goods as either tradable or nontradable. Traded goods can be exchanged across countries at relatively small transportation costs. Therefore, by traditional theory, the law of one price is assumed to hold for these tradable goods. In contrast, nontradable goods cannot be exchanged and their prices are determined by domestic factors only. Following this reasoning leads to the conclusion that movements in the real exchange rate should primarily be determined by the relative price changes between tradable and nontradable goods within several countries. But this theory is criticized by many authors in the literature. It is a classic question in macroeconomics of whether movements in the real exchange rate are mainly outcomes of fluctuations in the prices of tradable goods across countries or in relative price changes of tradable compared to nontradable goods.

Applying Engel's (1999) approach of variance decomposition, I examine the composition of Switzerland's real exchange rate fluctuations. More precisely, the variance of the real exchange rate is decomposed into the variance of the relative price of tradable goods across countries, the variance between nontradable goods within a country and a covariance therm. This will give us some insights about the importance of tradable and nontradable goods in explaining real exchange rate fluctuations.

The results of this approach depend critically on how prices of goods are measured. In particular there is no agreement in the literature on how tradable and nontradable goods prices should be measured. Therefore, two different indicators are used in this study to determine these price levels. The first one is a combination of export and import price indices, the second one is the producer price index. The advantages and disadvantages of these measurements are discussed in section 5.

However, the main finding of this study is that relative price changes between tradable and nontradable goods are important in explaining real exchange rate fluctuations. If import and export indices are used as measures of tradable goods prices, these relative price changes between tradable and nontradable goods actually account for more than 50 percent of real exchange rate movements.

This chapter is organized as follows. Section 4.2 surveys previous research and literature on the real exchange rate variance decomposition. Section 4.3 deals with the theory of the real exchange rate determination and the method of variance decomposition. The reported statistics for the time series are discussed in section 4.4 and the data used in this study are explained in section 4.5. Section 4.6 presents the results for the real exchange rate of Switzerland and finally, section 4.7 summarizes the main findings.

4.2 Previous Research

The purpose of this section is to survey the literature and previous research in the field of real exchange rate fluctuations. The extensive empirical literature concerning the long run properties of the real exchange rate, especially tests of Purchasing power parity (PPP), is not considered in this survey. A detailed overview can be found in Rogoff (1996) or in Mark (2001). Both authors report ambiguous findings regarding long-run PPP. In contrast, most of the literature about short- and medium-run real exchange rate fluctuations finds evidence denying the purchasing power parity. These studies attribute most of real exchange rate fluctuations to cross country differences in the prices of tradable goods. An important contribution to this literature is made by Engel (1999). He compares different measures of US-European, US-Canadian and US-Japanese real exchange rates and he concludes that changes in traded goods prices across countries account for almost all the variance of real exchange rates. For example, he finds that nearly 100 percent of the Mean Square Error (MSE) of the five-year change in US-European and US-Japanese real exchange rates is due to the MSE of traded goods. Using the same method of variance decomposition, Rogers and Jenkins (1995), Obstfeld (2001) and Chari et al. (2002) find that fluctuations in the relative price of nontraded goods account for less than 10 percent of the U.S. bilateral real exchange rate with several OECD Countries. These findings are confirmed by other empirical studies on medium-run real exchange rate determinants.Mendoza (2000) finds similar results for the US and Mexico using CPI-based prices for durable and nondurable goods to measure tradeable goods prices, whereas the prices of nontradable goods are measured by the price of services. Engel (2000) confirms his earlier results with US and Mexico data and Parsley (2001) reports the same results using data for the US and several Asian Countries. Similarly, Burstein et al. (2003) report that only 4.7 percent of the real appreciation during the first two years of Argentina's currency board were due to relative price changes of nontradable goods. Likewise, Lane and Milesi-Ferretti (2000) find evidence that real exchange rate movements in developing countries are primarily due to relative price changes of tradable goods.

Theses studies have provoked a number of objections that may be summarized as follows:

1. Using import and export price indices to measure tradable goods prices, Burstein et al. (2006) find that changes in the relative prices of nontradable goods account for at least 50 percent of real exchange rate fluctuations. The same calculations using retail prices confirm the results from the previous section, i.e. changes in nontradable goods do not much influence real exchange rates. They conclude that the results depend critically on the measurement of tradable goods and nontradable goods and that nontradable goods should be considered in real exchange rate models.

2. Engel (1999) and Rogers and Jenkins (1995) report some evidence that

the relative price of nontraded goods has a significantly higher influence on the U.S.-Canadian real exchange rate as compared to the U.S.-European real exchange rate.

3. Using the ratio of consumer price indices to producer price indices as a measure of the relative price between tradable and nontradable goods, Engel (1999) finds that fluctuations in the relative price of nontraded goods become more important in accounting for movements in the bilateral real exchange rate between some European Countries and the U.S..

4. In a study about deviations from the law of one price, Crucini et al. (2001) examine more than 5000 goods and services in the European Union for the years between 1975 and 1990. They find that the deviations from the law of one price are critically related to how the tradability of goods is measured.

This survey of the existing literature shows that there is no consensus on the causes of real exchange rate movements in the literature. Therefore, additional empirical work is needed. In the following, I supplement the existing literature by a theoretical and empirical study of Swiss real exchange rate movements.

4.3 Model

Basically, the real exchange rate is defined as

$$RER_t = \frac{P_t}{S_t P_t^*} \tag{4.1}$$

where S_t is the spot exchange rate (units of home country currency divided by unit of geometric-trade-weighted foreign currency), P_t and P_t^* denote the domestic and the foreign price levels, respectively.

In practice, the real exchange rate is measured as the ratio of the home country's CPI to the product of the CPI and exchange rates of the home country's trading partners:

$$RER_t^{cpi} = \frac{CPI_t}{\prod_{i=1}^{n}[S_t^i \cdot CPI_t^i]^{w_i}} \tag{4.2}$$

where, w_i denotes the weight of trade with country i in the total trade of the domestic country in a certain period. [1]

To study the sources of real exchange rate movements, I follow an approach proposed by Engel (1999). It is assumed that P_t is computed as a geometric average of the price of tradable goods (P_t^T) and the price of nontradable goods (P_t^N)

$$P_t = (P_t^T)^{1-\gamma}(P_t^N)^{\gamma} \tag{4.3}$$

which analogously holds for the foreign country

$$P_t^* = (P_t^{T*})^{1-\gamma^*}(P_t^{N*})^{\gamma^*}. \tag{4.4}$$

Here, γ and γ^* denote the share of tradable goods in the domestic and foreign CPI, whereas P_t^{T*} and P_t^{N*} represent the foreign price of tradable and nontradable goods, respectively.

Substituting equation 4.3 and 4.4 into 4.1 yields

$$\begin{aligned} RER_t^{cpi} &= \frac{P_t}{S_t P_t^*} \\ &= \frac{(P_t^T)^{1-\gamma}(P_t^N)^{\gamma}}{S_t(P_t^{T*})^{1-\gamma^*}(P_t^{N*})^{\gamma^*}} \\ &= \frac{(P_t^T)(P_t^N/P_t^T)^{\gamma}}{S_t(P_t^{T*})(P_t^{N*}/P_t^{T*})^{\gamma^*}} \\ RER_t^{cpi} &= \underbrace{\frac{P_t^T}{S_t P_t^{T*}}}_{DeviationfromPPP} \times \underbrace{\frac{(P_t^N/P_t^T)^{\gamma}}{(P_t^{N*}/P_t^{T*})^{\gamma^*}}}_{PriceMovementsofNontradables} \end{aligned}$$

I denote the logarithm of the CPI based real exchange rate as

$$rer_t^{cpi} = \log(RER_t^{cpi}) = \log\left(\frac{P_t}{S_t P_t^*}\right) \tag{4.5}$$

[1] There are two important notes concerning the consumer price index CPI.

1. First, the CPI is an index and it should be noted that the CPI based real exchange rate has no level information. It does not tell us which country has lower prices.
2. The basket of goods differs across countries. There are distortions concerning the weights of the single sections across countries.

We can now decompose movements in the real exchange rate into two components:

$$rer_t^{cpi} = rer_t^T + rer_t^N. \tag{4.6}$$

The variable rer_t^T is an index of the extent to which the prices of tradable goods, adjusted for the nominal exchange rate, are different across countries

$$rer_t^T = \log\left(\frac{P_t^T}{S_t P_t^{T*}}\right) \tag{4.7}$$

and rer_t^N reflects the inter-country difference of the relative price of nontradable goods to tradable goods

$$rer_t^N = \gamma \log\left(\frac{P_t^N}{P_t^T}\right) - \gamma^* \log\left(\frac{P_t^{N*}}{P_t^{T*}}\right) \tag{4.8}$$

Noting the definition 4.6, we can write the variance of rer_t^{cpi} as

$$var(rer_t^{cpi}) = var(rer_t^T) + var(rer_t^N) + 2cov(rer_t^T, rer_t^N). \tag{4.9}$$

In the calculations below, empirical measures for rer_t^{cpi} and rer_t^T are constructed to compute the variable rer_t^N using equation 4.6.

4.4 Reported Statistics

In order to describe the relation between the real exchange rate rer_t^{cpi} and the relative price of traded (nontraded) goods rer_t^T (rer_t^N), we first need to construct adequate statistics. In this section I briefly discuss the reported summary statistics. Most of these statistics are based on the sample variance

$$var(rer_t) = \frac{1}{n}\sum_{t=1}^{n}(rer_t - \overline{rer_t})(rer_t - \overline{rer_t}) \tag{4.10}$$

and on the sample covariance between rer_t and rer_t^N

$$cov(rer_t, rer_t^N) = \frac{1}{n}\sum_{t=1}^{n}(rer_t - \overline{rer_t})(rer_t^N - \overline{rer_t^N}). \tag{4.11}$$

In this paper the following summary statistics are reported:

1. Bravais-Pearson correlation coefficients

A simple measurement to capture the comovement of two time series is the correlation coefficient. I report the correlations between the real exchange rate rer^{cpi} and the nominal exchange rate S, as well as the correlation between the real exchange rate of tradable goods rer^{T} and the nominal exchange rate are reported.

2. The ratio of sample standard errors

The relation between two time series may also be analyzed by a comparison of volatilities. Here, this is done using different ratios of standard deviations. I report the ratios $\frac{\sqrt{var(rer^{N})}}{\sqrt{var(S)}}$ and $\frac{\sqrt{var(rer^{cpi})}}{\sqrt{var(S)}}$.

3. Elasticities

In this content, elasticities do not have a causal or structural interpretation. However, they are a convenient way to summarize the quantitative relation between the variables of interest. I consider both the elasticity of the real exchange rate rer^{cpi} and the real exchange rate of tradable goods, with respect to the nominal exchange rate S.

4. Variance decomposition

In this section I discuss statistical methods to assess the following question: How much of the overall real exchange rate's variance can be attributed to the variance of rer_t^T? The starting point is equation 4.9. To determine the total contribution of changes in rer_t^T to the variance of the real exchange rate $var(rer_t^{cpi})$ we need to decide on how to treat the covariance term, as already noted by Engel (1999). Following Mendoza (2000) I present different measures of variance ratios ($vardec_1, vardec_2$), with each of these ratios treating the covariance term differently. Additionally, I determine lower and upper bounds for the importance of movements in tradable and nontradable goods, respectively (see Burstein et al. (2006)).
First, the covariance between rer_t^T and rer_t^N is assumed to be zero, which only holds if rer_t^T and rer_t^N are independent random walks. The corresponding

variance ratio is defined as

$$vardec_1(rer_t) = \frac{var(rer^N)}{var(rer^N) + var(rer^T)} \tag{4.12}$$

This ratio was proposed by Engel (1999) analyzing Mexican real exchange rates. It's value is below 1 by definition. As Engel points out, this variance ratio is appropriate for industrial countries since the covariance is very small in these cases.

The second variance ratio attributes half of the covariance between rer^T and rer^N to rer^N:

$$vardec_2(rer_t) = \frac{var(rer^N) + cov(rer_t, rer_t^N)}{var(rer^{cpi})} \tag{4.13}$$

This measure was introduced by Mendoza (2000). He reported a significant influence from the covariance term.

Finally, lower and upper bounds for the importance of movements in nontradable goods rer_t^N are determined. The lower bound, L^N, is constructed by attributing the covariance term $cov(rer_t^T, rer_t^N)$ to fluctuations in the price of tradable (nontradable) goods when the covariance is positive (negative). The upper bound, U^N, is constructed by attributing the covariance term $cov(rer_t^T, rer_t^N)$ to fluctuations in the price of nontradable (tradable) goods when the covariance is negative (positive).

$$L^N = \begin{cases} \frac{var(rer_t^N)}{var(rer_t^{cpi})} & \text{if } cov(rer_t^T, rer_t^N) > 0 \\ \frac{var(rer_t^N)}{var(rer_t^{cpi})} + \frac{2cov(rer_t^N, rer_t^T)}{var(rer_t^{cpi})} & \text{if } cov(rer_t^T, rer_t^N) < 0. \end{cases}$$

$$U^N = \begin{cases} \frac{var(rer_t^N)}{var(rer_t^{cpi})} + \frac{2cov(rer_t^N, rer_t^T)}{var(rer_t^{cpi})} & \text{if } cov(rer_t^T, rer_t^N) < 0 \\ \frac{var(rer_t^N)}{var(rer_t^{cpi})} & \text{if } cov(rer_t^T, rer_t^N) > 0. \end{cases}$$

4.5 Data

4.5.1 Trading Partners

To assess the behavior of the real exchange rate we first have to determine the relevant trading partners of Switzerland. A standard procedure in the literature is to rank countries with respect to their trade share with a specific country, in this case Switzerland. Here, this is done using annual import and export data from 1980 to 2006.[2] The trade share of country i in Switzerland's total trade is calculated as

$$w_i = 0.5 * \left(\frac{exports_i^{swiss}}{exports^{swiss}} \right) + 0.5 * \left(\frac{imports_i^{swiss}}{imports^{swiss}} \right). \quad (4.14)$$

The Swiss National Bank (SNB) - which compiles these statistics - uses 24 countries to calculate the nominal and real exchange rate indices. Due to lack of data, I confine my calculations to the nineteen countries shown in Table 4.1.[3] The trade weights of these nineteen countries count for 83 percent of total imports and exports of Switzerland. As depicted in Figure 4.1, there is just a marginal difference between the SNB-version of the real exchange rate and the one constructed here.[4]
To get more information, the analysis is conducted not only for the aggregate real exchange rate, but also for those of a group of nine countries ("Medium Group") and a group of 5 countries ("Small Group"). The countries considered within these groups are depicted in Table 4.1 as well. Additionally, I present results from bilateral real exchange rate calculations for selected countries.

4.5.2 Price Series

The sample consists of quarterly data covering the period Q1 1970 to Q4 2006. The price series (nominal exchange rates, consumer price indices, producer price indices, import and export price indices) are from the IMF's International Financial Statistics. The nominal exchange rate indices (S_t), the foreign consumer price indices (P_t^*) and the foreign price indices of tradable goods (P_t^{t*}) are measured as trade weighted averages of the different countries' price series. As a measure of consumer prices, the consumer price indices (CPI) are used and not the harmonized indices of consumer prices (HICP) provided by the European Union. This is primarily due to the fact that the HICP is only

[2] Import and export data are from the IMF's Direction of Trade Statistics.

[3] Particulary import and export indices are not available for all 24 countries.

[4] The level of the real exchange rates are normalized to 1 in the year 1970, the beginning of the sample.

available since 1995. [5]

The first measure of tradable goods prices is constructed using import and export price indices.[6] More precisely, P_t^T is an equally weighted geometric average of import and export price indices. These indices measure prices of tradable goods at the docks. Important advantages of import and export price indices are that they measure the prices of goods that are actually traded and that they are not contaminated by nontradable components such as distribution costs.

As a second measure of tradable goods prices, the producer price index (PPI) is used. Similarly to the first measure above, the producer price index of Switzerland is used to measure the home- country price (P_t^T), whereas a trade weighted average of the other countries´ producer price series indicates the foreign tradable goods prices (P_t^{T*}).[7] The reason why producer prices are used as a second measure for tradable goods instead of retail prices (which is a common approach in the literature as well) is that retail prices are heavily contaminated. Following Burstein et al. (2003) this is mainly due to the costs of nontradable services such as wholesaling, retailing and transportation. But on the other hand it should be noted that the producer price indices generally excludes import prices.

4.6 Results

The constructed time series of S_t, RER_t^{cpi} and RER_t^T are shown in Figure 4.2 for all trading partners and in Figure 4.3 and 4.4 for the bilateral cases. [8] As already reported by Mussa (1986) we can observe similar movements over time

[5] I did all the calculations for the sample period 1995:2005 using HICP's and CPI's as measure for consumer price indices. Since the results are virtually the same, I deduce that they would remain the same for the period 1970:2005.

[6] When import or export price indices are not available, import and export unit value indices are used.

[7] Because for some countries (Belgium, France, Italy, Norway, Portugal) the producer price indices is not available, the measure is constructed using just fourteen trading partners. As the resulting nominal and real exchange rates just change at the margin, I abandon to show the calculations here.

[8] Again, the levels of the variables are normalized to one at the beginning of the sample (Q1 1970).

in the variables RER_t^{cpi} and S_t. On the other hand, RER_t^{cpi} and RER_t^T behave quite differently. This observation holds for the group as well as for the bilateral comparisons. However, the first graphical impression supports the thesis that exchange rate movements are not just due to price movements of tradable goods. This observation will be quantified in the next paragraph's interpretations of the results.

Table 4.2 reports the summary statistics and the results for the various measures of variance decomposition for the different country groups, whereby the prices of tradable goods are measured by import and export price indices. The reported summary statistics for rer_t^{cpi} and rer_t^T are described above: standard deviations, correlations and elasticities with respect to s_t. Following Burstein et al. (2006) the elasticities do not have a causal or structural interpretation. They represent the slope of a linear regression of either rer_t^{cpi} or rer_t^T on s_t and they summarize in a convenient way the quantitative relation between rer_t^{cpi}, rer_t^T and nominal exchange rates.

First, we consider the summary statistics for the relation between rer_t^{cpi} and s_t. The correlation coefficient $\rho_s^{rer^{cpi}}$ between the two variables is about 0.97 for all groups, implying a strong comovement. This observation is confirmed in the bilateral calculations shown in table 4.3, where the lowest correlation (in the case of the United Kingdom) is still 0.54. Again, this finding is consistent with Mussa (1986).

The ratio of standard deviations between rer_t^{cpi} and s_t lies between 0.56 for the Group *All* and 1.02 for the group *Small*. This leads to the conclusion that the volatility of s_t is about double the size compared to the volatility of rer_t^{cpi} except for Germany, where the volatility of rer_t^{cpi} and s_t is about the same. This in turn leads to a higher ratio for the Group *Small*, since here Germany's weight is quiet significant. I will refer to this fact later in this section. The elasticity of rer_t^{cpi} with respect to s_t is above 0.54 throughout all specifications. Summarizing these statistics, we detect a very close relation between rer_t^{cpi} and s_t.

In a second step, we explore the relation between the real exchange rate for tradable goods, rer_t^T, and the nominal exchange rate s_t. Here, the correlation coefficient $\rho_s^{rer^T}$ lies between 0.32 and 0.66 for the groups. In the bilateral case of Germany it is even negative. Theses values are clearly below the values of the correlation between rer_t^{cpi} and s_t.

The ratio of standard deviations between rer_t^T and s_t is about 0.35 regarding the country groups, implying that the value of the volatility of rer_t^T is about one third of the volatility of s_t. Again, Germany is an exception with a higher volatility for rer_t^T than for s_t. The elasticity of rer_t^T with respect to s_t is around 0.2 for the country groups.

Summarizing the results so far, the relation between rer_t^{cpi} and s_t is clearly stronger than the relation between rer_t^T and s_t.

Next, we assess the question of whether fluctuations in the real exchange rate are due to movements in the relative price of nontradable to tradable goods or to relative price changes of tradable goods across countries. The corresponding statistics are the two measures of variance decomposition and the lower and upper bounds for the significance of nontradable goods. They are reported in the last four columns of table 4.2 for the different groups and in table 4.3 for the bilateral summary.

The values of the two measures of variance decompositions are between 0.7 and 0.87 for the three country groups. The lower and upper bounds amount to 0.63 and 0.86, respectively. All these values lie between 0 and 1 and indicate that changes in the price of nontradable goods relative to the price of tradable goods are important to understand real exchange rate movements. In fact, they explain about two thirds of rer_t^{cpi} fluctuations. Considering the bilateral results, several values exceed unity. This is due to a negative covariance between rer_t^T and rer_t^N. [9] The values for these bounds are based on import and export price indices as measures for the tradable goods prices. In the next paragraph they are compared to the values of bounds based on other measures.

[9] The second variance ratio is greater than one if $var(rer_t^N) < -cov(rer_t^T, rer_t^N)$. Regarding the bounds, L^N is smaller than 0 if $var(rer_t^N) < -2cov(rer_t^T, rer_t^N)$ whereas U^N is greater than 1 if the covariance is negative and $var(rer_t^N) > var(rer_t^{cpi})$. The question is how to deal with these values, i.e. with the negative covariance. Since rer_t^T is primarily attributed to fluctuations in the nominal exchange rate, an increase in the latter goes along with higher volatility of the nontradable's relative price. This assumption is supported by empirical literature on the effects of inflation on relative price volatility. For example Lach and Tsiddon (1992) report increasing volatility of relative prices during inflation periods.

In a further step, I show how these results are sensitive to the choice of the measure for tradable goods. Table 4.4 displays a comparison between values of lower and upper bounds using two different measures for the price of tradable goods rer_t^T. The first column reports the values we discussed above using import and export price indices. In the second column the results using producer price indices are depicted. [10] The values are 0.19 for the lower bound and 0.58 for the upper bound. These values are clearly below the values in the first column. They suggest that changes in the price of nontradable goods relative to the price of tradable goods account for just about one third of rer_t^{cpi} fluctuations. This is about 50 percent less of what we found using import and export prices as measure of rer_t^T.

Finally, these results need to be compared with the findings from previous research. The results fromBurstein et al. (2006) considering several countries are confirmed here. Using import and export price indices to measure rer_t^T , they found a lower bound of 0.56 and an upper bound of 0.71. These values are very similar to this study's findings for Switzerland.[11] Using the second price measure, they found even lower values (a lower bound of -0.05 and an upper bound of 0.05).[12] On the other hand the results stand in a distinct contrast to the findings in the literature using retail prices, producer prices or GDP-deflators as price measures for rer_t^T. Examples for this string in the literature are Engel (1999),Chari et al. (2002) or Betts and Kehoe (2005).

4.7 Conclusion

This paper presents variance decompositions and summary statistics of Switzerland's real exchange rate from 1970 to 2006. The results depend critically on the measurement of tradable goods. Following Burstein et al. (2003), import and export price indices are the best indicators to approximate tradable goods.

[10] I abandon to show the other variance decompositions and summary statistics for other groups and bilateral examinations since the results provide no additional information.

[11] The bounds from Burstein et al. (2006) are median values of a basket of eleven countries (Australia, Canada, Denmark, Finland, Germany, Italy, Japan, Netherlands, Sweden, UK, USA).

[12] It should be considered that Burstein et al. (2006) used retail prices rather than producer prices as a second measure of rer_t^T.

They consider prices of traded goods at the docks, which are not contaminated by nontradable distribution costs. This is an advantage to traditional price measures as retail prices or producer prices. Using import and export price indices this study shows that real exchange rate fluctuations are not primarily due to relative price changes of tradable goods across countries (in contrast to Engel (1999) and many other authors). Moreover, relative price changes between tradable and nontradable goods within countries account for about two thirds of the real exchange rate movements. The remaining part is due to changes in the relative price of traded goods across countries. The results from this study for Switzerland provide evidence that relative price changes between tradable and nontradable goods should not be neglected in modeling real exchange rate fluctuations.

4.8 Appendix

Table 4.1: Trade weights Switzerland

Country	Trade Weights
Australia	0.47
Austria	3.71
Belgium	3.63
Canada	0.69
Denmark	0.94
Finland	0.65
France	9.98
Germany	26.62
Greece	0.39
Italy	9.09
Japan	3.51
Korea	0.58
Netherlands	3.80
Norway	0.41
Portugal	0.53
Spain	2.19
Sweden	1.48
United Kingdom	5.93
United States	8.31

Table 4.2: Group Summary Statistics using Import and Export Price Indices

	STD(s)	$\frac{\text{STD}(rer^{cpi})}{\text{STD}(s)}$	$\frac{\text{STD}(rer^{T})}{\text{STD}(s)}$	$\rho_s^{rer^{cpi}}$	$\rho_s^{rer^T}$	$\epsilon_s^{rer^{cpi}}$	$\epsilon_s^{rer^T}$	$Vardec_1$	$Vardec_2$	Bound L^n	Bound U^n
GROUP ALL	0.25	0.56	0.34	0.97	0.49	0.54	0.17	0.7	0.73	0.63	0.86
GROUP MEDIUM	0.25	0.76	0.34	0.98	0.32	0.73	0.11	0.83	0.87	0.8	0.96
GROUP SMALL	0.25	1.02	0.4	0.98	0.66	0.99	0.26	0.81	0.75	0.66	0.85

Quarterly Data 1970 Q1 - 2006 Q3

Table 4.3: Bilateral Summary Statistics using Import and Export Price Indices

	STD(s)	$\frac{\text{STD}(rer^{cpi})}{\text{STD}(s)}$	$\frac{\text{STD}(rer^{T})}{\text{STD}(s)}$	$\rho_s^{rer^{cpi}}$	$\rho_s^{rer^{T}}$	$\epsilon_s^{rer^{cpi}}$	$\epsilon_s^{rer^{T}}$	$Vardec_1$	$Vardec_2$	Bound L^n	Bound U^n
GERMANY	0.25	0.96	1.59	0.98	-0.42	0.92	-1.29	0.66	1.87	-1.72	5.45
ITALY	0.25	0.22	0.55	0.73	0.93	0.36	0.33	0.38	-0.63	-5.02	3.75
US	0.25	0.6	0.38	0.86	0.56	0.71	0.11	0.54	0.54	0.48	0.6
UK	0.25	0.31	0.36	0.54	0.67	0.33	0.18	0.37	0.23	-0.3	0.76

Quarterly Data 1970 Q1 - 2006 Q3

Table 4.4: Results for different Measures of Tradable Goods

	Lower Bounds on the Importance of Nontradables	Upper Bounds on the Importance of Nontradables
P^T measured by Import/Export Prices	0.63	0.86
P^T measured by Producer Prices	0.19	0.58

Switzerland Quarterly Data 1970 Q1 - 2006 Q3

Figure 4.1: Construction of Real Exchange Rate Indices

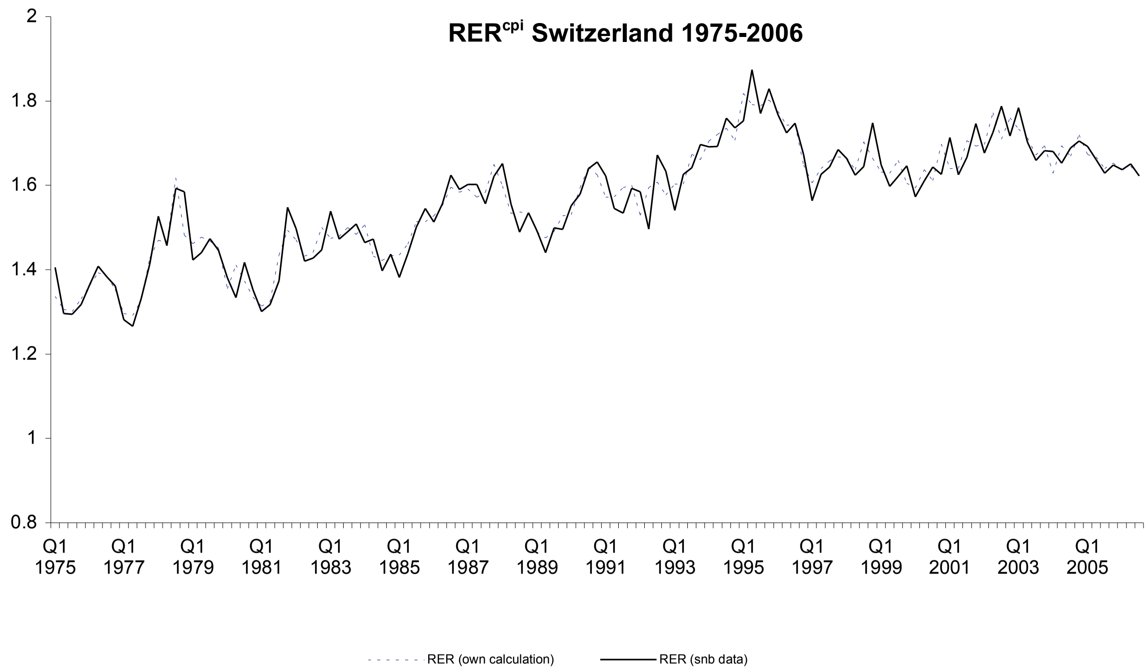


Figure 4.2: Real Exchange Rate and Components

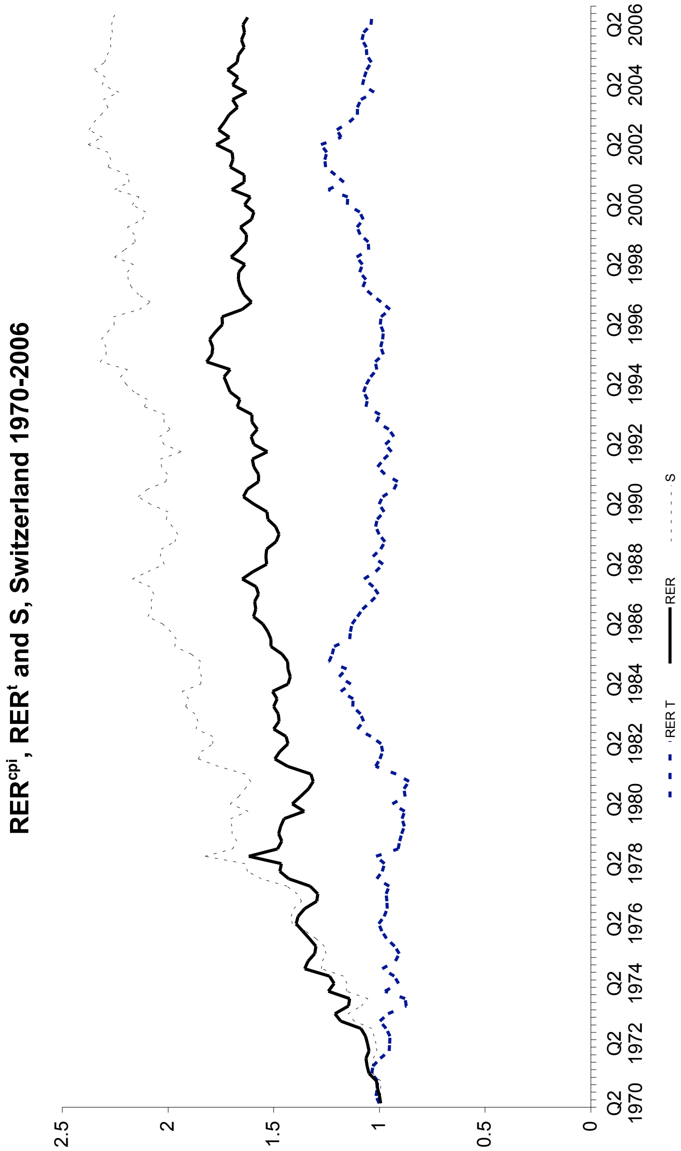
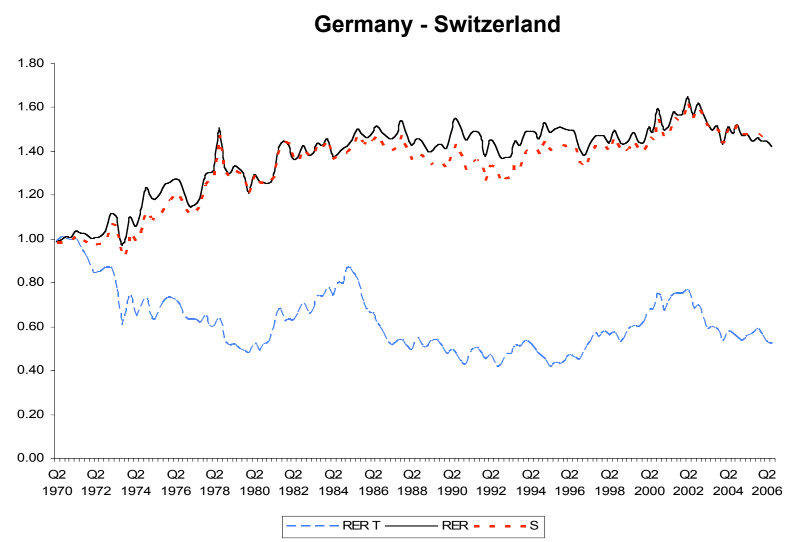


Figure 4.3: Bilateral Real Exchange Rate and Components



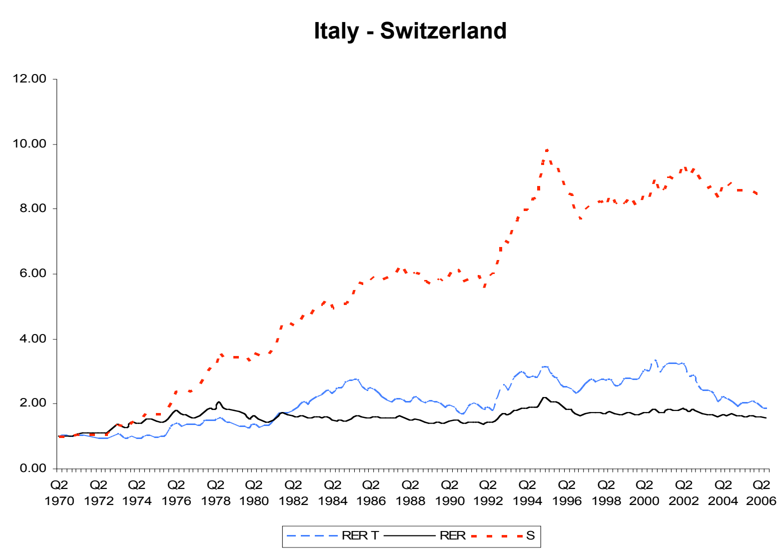
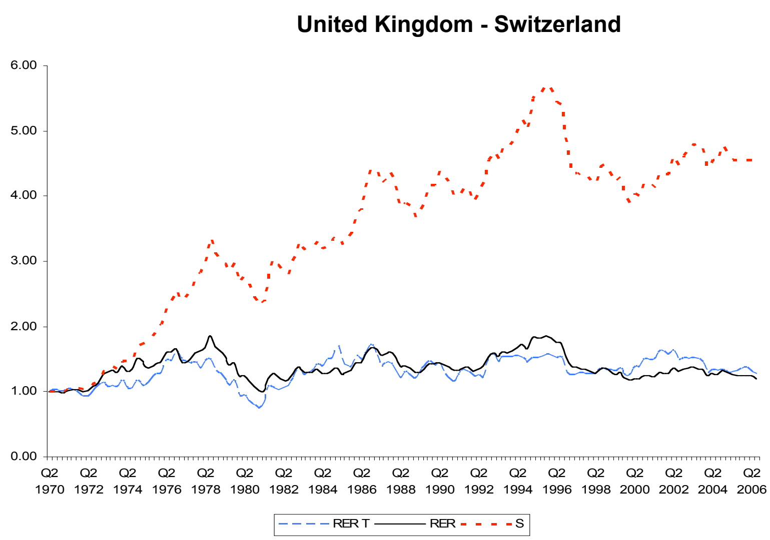
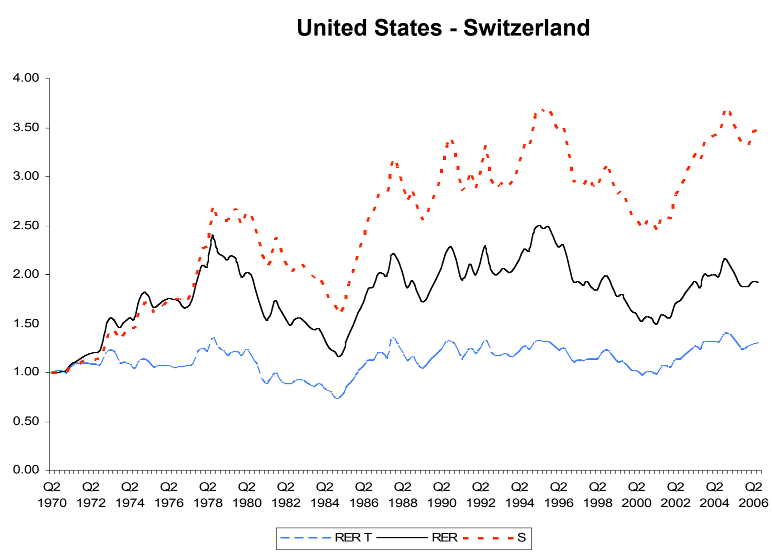


Figure 4.4: Bilateral Real Exchange Rate and Components





Chapter 5

Purchasing Power Parity: A nonlinear Approach

5.1 Introduction

This chapter approaches real exchange rate movements and determination from a monetary point of view. The monetary approach has a long tradition in literature and states in short words that the exchange rate between two economies is determined by relative supplies and demands for their monies. Within this approach it is often distinguished between a long run and a short run perspective (see Mussa (1979) for a more detailed overview). The short run behavior of the exchange rate is seen from an asset market perspective, i.e. the exchange rate can be compared to an asset price in an efficient market, equating supply and demand of each economy's money stock. In the long run, the equilibrium exchange rate is given by relative money supply and demands between the economies. This linkage between money and exchange rate requires a certain transmission mechanism which is given by a combination of both, the quantity theory of money and the Purchasing Power Parity (PPP). On the one hand, the quantity theory of money states that the money supply is an important determinant of the price level. On the other hand, PPP is based on the assumption that given free and frictionless markets, price differences across countries are immediately cleared by arbitrage trades. This study's focus lies on finding empirical evidence for PPP.

Apparently, the theory of PPP requires identical goods in both countries. If

prices of identical goods across countries do not diverge [1], the Law of one Price (LOOP) holds for the corresponding goods. An increase in the price of a good in the domestic country raises the opportunity to buy the same good in the foreign country and either consume or sell it at home. In both cases the price difference will diminish since domestic suppliers lower prices due to decreased demand, while foreign suppliers make respond to the increase in demand abroad and tend to raise prices. Both processes come to an end as soon as prices in both countries are equal again.
However, the adjustment process in the real world economy is not that simple. There exist several reasons why markets do not adjust prices as described above. Here, just some stylized facts are presented; a detailed survey is provided in Rogoff (1996). First, international trade is restricted by trade barriers, including duties or size constraints. Second, trade is inevitably associated with transport costs and finally there exist trade costs. The latter include additional marketing to serve a foreign market, adjustment of the products and translations of descriptions. These are reasonable and theoretically well based arguments for PPP not to hold. Empirical efforts of testing PPP face further problems:

1. Nontradable goods: Goods like a hair cut are not tradable. It is not always possible to distinguish clearly between tradable and nontradable goods, especially if consumer price indices (or parts of it) are used for compiling real exchange rates.

2. Different weights in the indices: The weights applied to goods or sectors may vary from country to country.

3. Imperfect Competition: Markets are frequently segmented. Companies with market power are able to charge different prices in different countries. If pricing to markets takes place, exchange rate movements can imply persistent deviations from LOOP (Lutz (2000) provides evidence for the car industry).

In this chapter I first show that Purchasing Power Parity can be detected empirically using nonlinear estimation techniques, i.e. a Threshold Autoregressive Model. Second, I demonstrate that using the results of the nonlinear

[1] Equal prices means $P_i = EP_i*$, where E is the nominal exchange rate, P_i and P_i* denote the price of good i in the domestic and foreign country, respectively.

estimations, fundamental variables explain real exchange rate movements more significantly. The results provide strong evidence in favor of nonlinear behavior of Switzerland's real exchange rate. Moreover, PPP can be shown to hold using nonlinear estimation techniques.

This chapter is organized as follows. The next section provides an overview of nonlinear real exchange rate modeling. Section 5.3 presents a detailed description of the applied econometric models, i.e. the linear and the nonlinear model, as well as the multivariate regression models. In section 5.4 I describe the test procedure of linear vs. nonlinear models. The data are described in section 5.5 and in section 5.6 the results are discussed. Section 5.7 concludes.

5.2 Nonlinear Exchange Rates

Early literature overwhelmingly applied linear models as to test for Purchasing Power Parity. In these models, the speed of adjustment of deviations from PPP are assumed to be uniform not only over time but also for all sizes of deviations. These assumptions make the linear model very easy to handle, but it is possible that the speed of adjustment rises as the deviation from PPP increases. Following Taylor and Taylor (2004), the idea of nonlinear adjustment in real exchange rates first appeared in Heckscher (1916). He proposed that the adjustment may not be linear because of transportation costs in international arbitrage trade. In other words, arbitrage trade does not take place until a certain threshold of price deviations is passed. Starting in the 1990s this idea was implemented in various studies (see for example Williams and Wright (1992), Dumas (1992), Sercu et al. (1995)). These studies are characterized by a common implementation of transportation or other transaction costs in their models: they create a band of inaction. Within this band the marginal costs of arbitrage trade exceed the marginal returns. In the empirical models this band of inaction is implemented by allowing the autoregressive parameter to vary. Transaction costs of goods arbitrage and nominal exchange rate speculations lead the real exchange rate to move randomly until a certain threshold is passed. This threshold marks exactly the size of deviation where arbitrage trade gets profitable. Once this threshold is breached and arbitrage takes place, the real exchange rate is forced to revert back towards its long term mean. These models are known as Threshold Autoregressive Models (TAR).

In the recent literature there are several studies exploring nonlinearities in real exchange rates using TAR models. Obstfeld and Taylor (1997) examine subindices of consumer prices of 32 cities and countries using data from 1980 to 1995. Measuring half-lives and thresholds, they find considerable variation across countries and goods. In their study, Cheung et al. (2001), point to difficulties in measuring mean reversion of real exchange rates applying nonlinear models based on aggregated price indices. They show that transaction costs and the speed at which arbitrage takes place differ substantially across different goods. Using annual data, Sarno et al. (2004) explore bilateral real exchange rates of the G7 countries from 1994 to 2002. They report strong evidence in favor of the Threshold Autoregressive model with thresholds and half-lives varying strongly across countries. Finally, Juvenal and Taylor (2008) examine in a very recent study the bilateral real exchange rates of nine European countries (Switzerland is not included). They distinguish between 16 sectors and again report varying thresholds and half-lives.

With respect to nonlinearities, this study examines the performance of a nonlinear TAR-model compared to a traditional linear AR model in explaining PPP for Switzerland and it's most important trading partners.

5.3 Econometric Modeling

The real exchange rate between two currencies corresponds to the nominal exchange rate, adjusted for relative price levels in both countries. For the case of Switzerland and one of its trading partners i, we can define the bilateral real exchange rate at time t as

$$q_t^i = s_t^i + p_t^i - p_t^{SW}$$

where q_t^i is the logarithm of the real exchange rate, which may be viewed as the deviation from Purchasing Power Parity[2]. However, s_t^i denotes the logarithm of the nominal exchange rate between the Swiss franc and country's i currency,

[2]It should be noted that here the real exchange rate measures the real Swiss-franc price of the foreign currencies. In contrast, in chapter 4 the real exchange rate is expressed as the real foreign price of the Swiss franc.

p_t^i is the logarithm of the prices in country i and p_t^{SW} denotes the logarithm of Switzerland's prices. Using this fundamental equation, the next subsections show how to apply linear and nonlinear models to test for a mean reverting process in deviations from PPP.

5.3.1 Linear Model

The Purchasing Power Parity hypothesis holds if the real exchange rate is determined by a mean reverting, i.e. a stationary process. In a linear framework one can apply a simple unit root test. I considered the Augmented Dickey Fuller (ADF) test of the form

$$\Delta q_t = \gamma_0 q_{t-1} + \sum_{p=1}^{P} \gamma_i \Delta q_{t-p} + u_t$$

where q_t is the logarithm of the real exchange rate, p denotes the lag length and u_t is the error term. The null hypothesis of a unit root ($H_0 : \gamma_0 = 0$) is tested against the alternative of a stationary real exchange rate ($H_1 : \gamma_0 < 0$).

5.3.2 Nonlinear Model

Nonlinear models using thresholds are known as Threshold Autoregressive Models (TAR) and were first applied in the context of real exchange rates by Balke and Fomby (1997). A special case of a TAR model is the self exiting threshold autoregressive (SETAR) model. Here, the threshold variable is a lagged dependent variable. We can write a simple three regime SETAR model as

$$\begin{aligned} q_t &= \sum_{p=1}^{P} \alpha_p q_{t-p} + \epsilon_t \qquad if \quad -\tau \leq q_{t-d} \leq \tau \\ q_t &= \tau[1 - \sum_{p=1}^{P} \beta_p] + \sum_{p=1}^{P} \beta_p q_{t-p} + \epsilon_t \quad if \quad q_{t-d} > \tau \\ q_t &= \tau[1 - \sum_{p=1}^{P} \beta_p] + \sum_{p=1}^{P} \beta_p q_{t-p} + \epsilon_t \quad if \quad q_{t-d} < -\tau \end{aligned}$$

where q_t is the real exchange rate, τ denotes the threshold parameter and p is the lag length selected in the linear model using the Akaike Criterion. The delay parameter d measures the time agents need to react to deviations from LOOP and the error term ϵ_t is assumed to be *iid* normally distributed. As suggested by Obstfeld and Taylor (1997), I assume that the thresholds are symmetric. This implies in a two-country model that transaction costs are equal in both countries, independent of whether prices are higher in one country or the other. Within the two symmetric thresholds the model allows for a band of inaction, since transaction costs of commodity trading are too big compared to arbitrage profits. This implies that in this inner regime the real exchange rate follows a unit root process and shows no tendency of mean reverting. However, in the outer regime the real exchange rate is assumed to exhibit a stationary autoregressive process. Hence, q_t has a tendency to move back to the edge of the band when it lies outside the band.

Using the indicator functions $1(q_{t-d} \leq \tau)$, $1(q_{t-d} > \tau)$, $1(q_{t-d} < -\tau)$ and solving the model above with respect to the first difference Δq_t, yields the following equation:

$$\begin{aligned}
\Delta q_t &= \left[\sum_{p=1}^{P} \alpha_p \Delta q_{t-p}\right] * 1(q_{t-d} \leq \tau) \\
&+ \left[(\beta_1 - 1)(q_{t-1} - \tau) + \sum_{p=1}^{P} \beta_p q_{t-p} - \tau\right] * 1(q_{t-d} > \tau) \\
&+ \left[(\beta_1 - 1)(q_{t-1} + \tau) + \sum_{p=1}^{P} \beta_p q_{t-p} + \tau\right] * 1(q_{t-d} < -\tau) + \epsilon_t
\end{aligned}$$

In order to show the estimation procedure I rewrite the model above in matrix notation:

$$q_t = A_t(\tau, d)'\Lambda + \epsilon_t \tag{5.1}$$

where

$$A_t(\tau, d)' = [X'1(q_{t-d} \leq \tau) \quad Y'1(q_{t-d} > \tau) \quad Z'1(q_{t-d} < -\tau)]$$

with

$$X = \begin{pmatrix} \Delta q_{t-1} \\ \Delta q_{t-1} \\ \vdots \\ \Delta q_{t-p} \end{pmatrix}, Y = \begin{pmatrix} q_{t-1} - \tau \\ q_{t-2} - \tau \\ \vdots \\ q_{t-p} - \tau \end{pmatrix}, Z = \begin{pmatrix} q_{t-1} + \tau \\ q_{t-2} + \tau \\ \vdots \\ q_{t-p} + \tau \end{pmatrix}$$

and

$$\Lambda' = [\alpha \quad \beta \quad \beta]$$

with

$$\alpha = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \vdots \\ \alpha_p \end{pmatrix}, \beta = \begin{pmatrix} \beta_1 - 1 \\ \beta_2 \\ \vdots \\ \beta_p \end{pmatrix}$$

The parameters to be estimated are τ, d and the vector Λ. Hansen (1997) shows that Ordinary Least Squares (OLS) can be applied using a sequential procedure. For given values of τ and d the OLS estimate of Λ is

$$\Lambda' = \left[\sum_{t=1}^{T} A_t(\tau, d) B_t(\tau, d)' \right]^{-1} \left[\sum_{t=1}^{T} A_t(\tau, d) \Delta q_t \right]$$

with the residuals

$$\hat{\epsilon}_t(\tau, d) = \Delta q_t - A(\tau, d)' \hat{\Lambda}(\tau, d)$$

and the residual variance

$$\hat{\sigma}^2(\tau, d) = \frac{1}{T} \sum_{t=1}^{T} \hat{\epsilon}_t(\tau, d)^2$$

Since the parameters τ and d are not known we cannot simply estimate equation (5.1). Hansen (1997) suggest a grid search procedure which estimates equation (5.1) for each possible combination of τ and d. The estimates for τ and d chosen by the algorithm are those, minimizing the sum of squared residuals. This can be written as

$$(\hat{\tau}, \hat{d}) = \arg\min_{\tau, d} \quad \hat{\sigma}^2(\tau, d)$$

where d is an integer value between 1 and $\bar{d} \leq p$, and $\underline{\tau} \leq \tau \leq \bar{\tau}$.

5.3.3 Multivariate Model

After the nonlinear estimation each observation in the time series of real exchange rates can be assigned to the inner band or the outer band. The

series in the outer band is thereby characterized by a mean reversion process whereas within the band deviations from PPP follow a random walk. This again implies that the real exchange rate movements in the outer band should be driven more by fundamental variables compared to movements in the inner band. This assumption is tested using fundamental explanatory variables.
I estimate five various combinations of the following general specification:

$$\begin{aligned} rer^i = \alpha &+ \beta_1(m - m^*) + \beta_2(y - y^*) + \beta_3(r^{short} - r^{short*}) \\ &+ \beta_4(r^{long} - r^{long*}) + \beta_5(\pi^e - p^{e*}) + \beta_6 TB^* + \beta_7 TB + \epsilon, \end{aligned}$$

where rer_i^j is the bilateral real exchange rate between Switzerland and country i, $m - m^*$ denotes the logarithm of the ratio between domestic and country i's money supply and $y - y^*$ corresponds to the logarithm of the ratio of domestic to foreign income.Furthermore, $r^{short} - r^{short*}$ is the short run interest rate differential, whereas $r^{lonh} - r^{long*}$ denotes the long run interest rate differential between the two countries. The difference of expected inflation is captured by the term $\pi^e - \pi^{e*}$, TB and TB^* denote the domestic and foreign trade balance, respectively, and ϵ is the disturbance term.
This specification of the estimation equation captures different versions of the monetary approach in exchange rate theory. Several modifications of the equation above are estimated to get more robust results and to avoid multicollinearity [3]. This general specification is similar to the model in the Meese and Rogoff (1983) seminal contribution where they tested monetary exchange rate models against the random walk hypothesis.

5.4 Testing the Nonlinear Model

In a next step it is important to test whether the nonlinear model above performs statistically better than a linear AR(p). However, conventional test statistics to test the null hypothesis of a AR(p) model against a SETAR model have non-standard asymptotic distributions. This is due to the fact that the threshold

[3]The estimations were tested regarding multicollinearity. The money supply and the interest rates are characterized by a significant correlation, i.e. $-.73$ for the long term interest rate and $-.23$ for the short term interest rate, respectively. This fact is considered by estimating models (3)-(5) without the money supply variable.

parameter τ as well as the delay parameter δ are not identified under the null hypothesis of linearity. Therefore, I follow the methodology proposed by Hansen (1997).

According to Davies (1977)[4], a standard F-statistic would be applied if the errors are *iid*:

$$F_n(\tau, d) = \frac{\tilde{\sigma}^2 - \hat{\sigma}^2(\tau, d)}{\hat{\sigma}^2(\tau, d)}$$

where $\tilde{\sigma}^2$ and $\hat{\sigma}^2(\tau, d)$ denote the estimated residual variance with respect to the AR(p) and to the SETAR model, respectively. Since the parameters (τ, d) are not identified in the linear model, $F_n(\tau, d)$ is asymptotically not χ^2 distributed. This problem can be addressed by approximating the asymptotic distribution using bootstrapping.

Let u_t^* be *iid* $N(0,1)$ random draws and set $q_t^* = u_t^*$. Regress q_t^* on the observations q_{t-1}, q_{t-2},...q_{t-p} using the linear model to obtain the residual variance $\tilde{\sigma}^2$. Regress q_t^* on the observations q_{t-1}, q_{t-2},...q_{t-p} using the nonlinear model to obtain the residual variance $\hat{\sigma}^2(\tau, d)$. Using these residual variances the following F-statistic can be constructed

$$F_n^*(\tau, d) = \frac{\tilde{\sigma}^{*2} - \hat{\sigma}^{*2}(\tau, d)}{\hat{\sigma}^{*2}(\tau, d)}$$

Hansen (1996) shows that the distribution of F_n^* converges weakly in probability to the null distribution of F_n, so that repeated draws for F_n^* may be used to approximate the asymptotic null distribution of F_n. The bootstrap approximation to the asymptotic p-value of the test is determined by the percentage of bootstrap samples F_n^* exceeding the observed F_n.

5.5 Data

This study considers the bilateral real exchange rates of Switzerland with respect to it's most important trading partners. These countries are Germany with

[4]In this paper the standard method of Davies (1977) has been applied even though Andrews (1993) show that the power of the test can be improved by choosing Bayesian weighted averages for F_n instead of the maximum.

a trade share in Switzerland's total trade of 27%, France (9%) [5], Italy (9%), United States (8%) and United Kingdom with a share of 6%, respectively. Using monthly data the sample captures the period between 1973:01 to 2008:5.

The selection of a price index to construct the real exchange rate is of crucial importance in assessing Purchasing Power Parity. Many authors criticize that the usually applied consumer price indices (CPI) as well as the producer price indices do not satisfy the requirements of PPP theory. Well known problems are measurement errors and aggregation biases (see e.g. Imbs et al. (2005)). However, the main point is that they do not distinguish between tradable and nontradable goods. Burstein et al. (2006) propose to replace the CPI by export and import price indices, respectively. Details about characteristics, construction of the indices and data source can be found in chapter 4, section 4.5.2.

Data for the multivariate estimations are from datastream and include money supply, national income, short term interest rates, long term interest rates and inflation expectations. [6] The variable for money supply is M1, national incomes are approximated by the OECD's composite indicator [7] and three month interest rates are used for short-term rates. The long term interest rates are captured by the 10-year government bond yields. Finally, the inflation expectations are approximated by a moving average of the inflation values of the last twelve months, as proposed by Frankel (1981).

5.6 Results

In this section I discuss the results of the empirical analysis. First, the unit root tests of the linear model are explored. Next I evaluate the performance of the nonlinear model compared to the linear model. The results of the threshold model, i.e. the value of the threshold, the delay parameter and the speed of

[5] France is not considered in the estimations, since monthly data for import and export price indices are not available before 1991.

[6] The multivariate analysis focus on the bilateral real exchange rate between Switzerland and it's main trading partner Germany.

[7] Usually GDP is considered as the income variable, which is available quarterly and this study relies on monthly data. Another alternative is the industrial production which has a monthly frequency for most of the countries, but quarterly for Switzerland.

mean reversion are examined at the end of this section.

5.6.1 Unit Root Tests

Table 5.1 shows the results of the augmented Dickey Fuller tests. I tested the hypothesis of a unit root in the real exchange rates, indicating non stationary processes. Furthermore, the Akaike criterion was applied to select the optimal lag length. At 10% significance this hypothesis cannot be rejected in 5 out of 8 cases, whereas at the 5% level in 7 out of 8 cases the null cannot be rejected. Summarizing, based on linear models, real exchange rates for Switzerland show no tendency to be mean reverting, i.e. to follow a stationary process.

5.6.2 Tests of Non-Linearity

In this section I discuss the results of the Non-Linearity test, i.e. whether the nonlinear SETAR model performs statistically better than a linear AR(p) model. The results are reported in Table 5.2. The null hypothesis of linearity is rejected in 7 out of 8 estimations at a level of 5% and in 3 estimations at a level of 1%, respectively. The only exception is the real exchange rate for all goods between Switzerland and the United Kingdom, where the hypothesis of linearity cannot be rejected. These results provide strong evidence that in the case of Switzerland and its main trading partners the bilateral real exchange rates exhibit nonlinear behavior. This in turn implies that linear tests on mean reversion are misspecified and may not capture the whole story.

5.6.3 Thresholds

The estimated thresholds are shown in Table 5.2. As one would expect, within most of the countries thresholds of the real exchange rate for tradable goods are significantly lower than thresholds of the real exchange rate containing all goods. The only exception is Germany, where the threshold for tradable goods is 4.3% whereas the threshold for all goods is slightly lower at 3.6%. The most distinct variation is observed with respect to Italy. Here, the threshold for tradable goods has a value of 3.5%, whereas the threshold for all goods is about 5 times higher and lies at 19%. For the United Kingdom values of 12% for tradable goods and 15% for all goods, respectively, are reported. Considering the United States the values are lower, i.e. 1.2% for tradable goods and 2% for all goods. It should be noted that the size of the thresholds for the United States cannot be compared directly to the other countries, since data for the US are not available before 1988.

5.6.4 Delay Parameter

Obstfeld and Taylor (1997) restrict the delay parameter to 1 since they expect that deviations from the LOOP do not exhibit a high degree of stickiness, which would result in a high value of d. However, in this study the delay parameter d is determined by the grid search and varies from case to case. The optimal values are shown in Table 5.2. The values of d lie between 1 and 4, where the latter is the case for tradable goods with Italy. On average, the delay parameter is equal to 2.
Since in this estimations the value of the delay parameters deviate from 1 in 5 out of 8 cases, it makes sense not to restrict d to 1. However, results do not change significantly if one fixes d to 1.

5.6.5 Speed of mean reversion

There are different measures of the speed of mean reversion in the literature. The most common is half-live, indicating the time to shorten the effect of an initial shock by 50%. Table 5.3 reports the speed of mean reversion for each country and price indices. Since in the SETAR model the real exchange rate is assumed to follow a random walk within the thresholds, it is reasonable to measure mean reversion toward the band $[-\tau, \tau]$. Therefore, the speed of convergence λ is given by the root of the outer regime

$$\lambda = \sum_{p=1}^{P} \beta_p$$

Since we focus on the root of the outer regime, the half-lives can be computed as in a standard linear model

$$h = \frac{\ln(0.5)}{\ln(\lambda)}$$

This is the standard measure of half-lives in the literature of TAR and SETAR models. A caveat in interpreting the half-lives in a nonlinear threshold framework is the fact that it does not consider the mean reversion in the inner bands. The values are therefore not directly comparable to the half-lives given by linear models.
However, the results in table 5.3 show that the half-lives of a deviation from the LOOP lie between 13 and 67 months. For the real exchange rate of tradable goods with Germany, it takes 21 months for half of an initial deviation to dissipate, compared to 51 months for the total real exchange rate. This is double the time for the latter exchange rate. The same is true for the United Kingdom. Here, it takes between 13 and 29 months for half of a deviation from the LOOP to dissipate. With the only exception of Italy, the values are lower for the real exchange rate of tradable goods compared to the total real exchange rate.

5.6.6 Multivariate Regressions

The results of the multivariate regression show significant differences between the real exchange rate time series in the inner band of the thresholds and in the outer band. As expected, the correlation between real exchange rate and the explanatory variables are much stronger in the outer band, whereas in the inner band the regression are characterized by a relative small explanatory power. Table 5.4 reports the results for the regression models in the outer band. Throughout all regression models, the income ratio between Switzerland and Germany $y - y*$ has a strong negative effect on the bilateral real exchange rate. Considering the problem of multicollinearity due to the correlation between the money supply and the interest rates, the most interesting findings are shown in models (3) to (5), where money supply does not enter the regression equation. Both, short term and long term interest rate spreads are highly significant and have the strongest effect on the real exchange rate in model (5), where trade balances are not considered. The inflation differential $\pi^e - \pi^{e*}$ has a negative effect but is not significant in models (2) and (5). Since a positive trade balance tends to appreciate the domestic currency and therefore to decrease the exchange rate, the trade balance of Germany has a positive effect whereas Switzerland's trade balance has a negative impact on the real exchange rate.

Both coefficient are highly significant throughout all regression models. Table 5.5 shows the results for the total time series, without distinction of inner and outer bands. Basically, the results are in the same line as the ones in the outer band. The difference is that the coefficients are clearly smaller and less significant than above. Throughout all regression models this yields a distinct smaller R-squared. Finally, Table 5.6 summarizes the regression results of the inner band. As expected, these results do not have relevant explanatory power in characterizing real exchange rate fluctuations.

5.7 Conclusion

Convincing as the theory of Purchasing Power Parity may be, finding empirical evidence proves difficult. This study shows mean reversion for Switzerland's main bilateral real exchange rates using a nonlinear Threshold Autoregressive model. First, it is shown that the nonlinear model performs significantly better than a linear Autoregressive model. Second, price series for all goods and only tradable goods are used to construct real exchange rates. As expected, mean reversion tend to be faster if only tradable goods are considered. While inside the thresholds, the real exchange rate follows a random walk, it is characterized in the outer band by a mean reversion process. Finally, multivariate regressions show that in the outer band, where the real exchange rate is mean reverting, fundamental variable have significantly more explanatory power than in the inner band or in the total time series of real exchange rates.

5.8 Appendix

Table 5.1: Augmented Dickey-Fuller Tests

Country	Series	Lags	t stat	p*
Germany	Total	2	-2.822	0.056
	Tradable	2	-2.109	0.242
Italy	Total	6	-2.508	0.114
	Tradable	1	-3.451	0.011
United Kingdom	Total	1	-3.052	0.031
	Tradable	4	-2.519	0.112
United States	Total	2	-2.031	0.273
	Tradable	2	-2.266	0.184
Test critical values:	1% level		-3.45	
	5% level		-2.89	
	10% level		-2.57	

Table 5.2: Nonlinear Estimation

Country	Series	threshold	delay	lag	p-value
Germany	Total	0.036	2	2	0.0000
	Tradable	0.043	2	2	0.0000
Italy	Total	0.192	3	6	0.0000
	Tradable	0.035	1	1	0.0720
United Kingdom	Total	0.148	1	1	0.2680
	Tradable	0.116	4	4	0.0140
United States	Total	0.020	2	2	0.0220
	Tradable	0.012	1	2	0.0400

Table 5.3: Half-lives

Country	Series	ω	Half lives
Germany	Total	0.99	51
	Tradable	0.97	21
Italy	Total	0.95	13
	Tradable	0.99	67
United Kingdom	Total	0.98	29
	Tradable	0.95	13
United States	Total	0.97	21
	Tradable	0.97	20

Table 5.4: Real Exchange Rate, outer band

Dependent variable: rer_{SW}^{GE}	(1)	(2)	(3)	(4)	(5)
m-m*	-0.2891	-0.3219			
	(0.0000)	(0.0000)			
y-y*	-1.2796	-0.6939	-2.3877	-2.1398	-1.2722
	(0.0000)	(0.0240)	(0.0000)	(0.0000)	(0.0130)
r-r* (short term)	-0.0106	-0.0085	-0.0154		-0.0161
	(0.0010)	(0.0050)	(0.0040)		(0.0040)
r-r* (long term)	0.0040		0.0737	0.0624	0.0898
	(0.5020)		(0.0000)	(0.0000)	(0.0000)
$\pi^e - \pi^{e*}$	-0.0046	-0.0014	-0.0150	-0.0206	-0.0073
	(0.1000)	(0.6150)	(0.0010)	(0.0000)	(0.1110)
tb germany	0.0052		0.0100	0.0105	
	(0.0000)		(0.0000)	(0.0000)	
tb switzerland	-0.0531		-0.1116	-0.1083	
	(0.0000)		(0.0000)	(0.0000)	
Constant	-0.3596	-0.3702	0.0723	0.0707	0.1662
R-squared	0.8283	0.8086	0.5411	0.5270	0.4652
observations	289	289	289	289	289

p-values in parentheses

Table 5.5: Real Exchange Rate, total time series

Dependent variable: rer_{SW}^{GE}					
	(1)	(2)	(3)	(4)	(5)
m-m*	-0.2677	-0.2533			
	(0.0000)	(0.0000)			
y-y*	-1.1157	-0.3639	-2.2140	-2.0093	-1.1241
	(0.0000)	(0.2120)	(0.0000)	(0.0000)	(0.0020)
r-r* (short term)	-0.0032	-0.0012	-0.0125		-0.0068
	(0.2940)	(0.6540)	(0.0030)		(0.1130)
r-r* (long term)	-0.0025		0.0596	0.0506	0.0572
	(0.6390)		(0.0000)	(0.0000)	(0.0000)
$\pi^e - \pi^{e*}$	-0.0048	0.0022	-0.0133	-0.0179	-0.0067
	(0.0990)	(0.4500)	(0.0010)	(0.0000)	(0.0940)
tb germany	0.0030		0.0057	0.0056	
	(0.0010)		(0.0000)	(0.0000)	
tb switzerland	-0.0719		-0.0951	-0.0858	
	(0.0000)		(0.0000)	(0.0000)	
Constant	-0.3233	-0.2789	0.0754	0.0763	0.1151
R-squared	0.6736	0.6298	0.3728	0.3595	0.3038
Observations	425	425	425	425	425

p-values in parentheses

Table 5.6: Real Exchange Rate, inner band

Dependent variable: rer_{SW}^{GE}					
	(1)	(2)	(3)	(4)	(5)
m-m*	-0.0140	-0.0139			
	(0.2390)	(0.0410)			
y-y*	0.2760	0.2439	0.2316	0.2175	0.1959
	(0.1090)	(0.1040)	(0.1680)	(0.1940)	(0.1990)
r-r* (short term)	0.0024	-0.0001	0.0017		-0.0007
	(0.1800)	(0.9200)	(0.3050)		(0.6620)
r-r* (long term)	0.0001		0.0030	0.0041	0.0026
	(0.9840)		(0.1770)	(0.0280)	(0.1440)
$\pi^e - \pi^{e*}$	0.0065	0.0069	0.0055	0.0063	0.0057
	(0.0080)	(0.0020)	(0.0160)	(0.0040)	(0.0070)
tb germany	-0.0015		-0.0015	-0.0014	
	(0.0000)		(0.0000)	(0.0000)	
tb switzerland	0.0158		0.0168	0.0143	
	(0.0030)		(0.0020)	(0.0030)	
Constant	0.0049	-0.0084	0.0262	0.0256	0.0119
R-squared	0.2025	0.1021	0.1928	0.1871	0.0879
Observations	136	136	136	136	136

p-values in parentheses

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