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Revisiting German labour market reform effects—a panel data analysis for occupational labour markets

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Abstract
The role of the 2000's German labour market reforms in boosting the German economy has been widely discussed. Considering that one of the main objectives of these reforms was to improve the matching process on the labour market, I use high-frequency administrative data to present new details regarding the development of job-matching performance from 2000 to 2011. Matching productivity increased during all reform stages. Increases in matching productivity have become smaller from 2009. The analysis shows also differences and commonalities in the matching productivity changes on occupational labour markets.

JEL Classification: C23, J44, J64

Keywords: Labour market reforms, Unemployment, Vacancies, Matching model, Panel data, Occupational labour markets

1 Introduction

The tenth anniversary of the German labour market reforms has been accompanied by a lively discussion regarding the contributions of these reforms to the development of the German labour market and the German economy as a whole (Burda and Hunt 2011; Dustmann et al. 2014; Fitzenberger 2009; Gartner and Fujita 2014; Hertweck and Sigrist 2012; Krebs and Scheffel 2013; Möller 2010; Rinne and Zimmermann 2012, 2013). Whether the results of various studies imply that German labour market policy in the last decade can thus be regarded as a role model for other countries seems to depend on policy makers' expectations for these reforms. In particular, it is debatable whether the reforms were expected to boost the entire German economy and raise its competitiveness. However, it is clear that one of the main objectives of the reforms was explicit in its mandate to improve matching processes on the German labour market (Hartz et al. 2002) because Germany suffered from a high degree of structural unemployment in the early 2000s.

In this paper, I present comprehensive details regarding the development of the job-matching function and its performance before and after the reforms took effect. The German labour market reforms were implemented in four stages and spanned the period from 2003 to 2005. The laws that were implemented are referred to as Hartz I to Hartz IV and were named after the head of the expert commission that worked out the substantial propositions for the German labour market reforms (Hartz et al. 2002). In January

2003, the first two reform stages were implemented (Hartz I and II). The third stage, Hartz III, followed in January 2004 and the last stage, Hartz IV, was implemented in January 2005. Additionally and following these reform stages, in 2006, the maximum number of months of unemployment benefits was reduced. Few studies have shed light on the direction and structure of the reform's effects on job matching productivity. Fahr and Sunde (2009) reported better matching for the aggregated German labour market after the first three reform stages (Hartz I/II and Hartz III) had been implemented. Klinger and Rothe (2012) used newer and richer data, which enabled these authors to analyse the last reform stage (Hartz IV in 2005) and to distinguish between long- and short-term unemployed. Overall, these authors also found that the reforms had positive effects on matching efficiency, particularly after Hartz I/II (2003) and III (2004) were introduced. In addition, they found stronger reform effects for the long-term unemployed. However, the last reform stage (Hartz IV)—consisting of a fundamental change in the tax-financed and means-tested unemployment benefit scheme—did not lead to further positive effects. The same authors explain this finding using statistical effects because the number of unemployed increased sharply in 2005 due to the changes under Hartz IV. Hillmann (2009), who also used newer data, found that Hartz IV had positive effects; her analysis constructed the reform dummy differently for Hartz IV.[1] Finally, Klinger and Weber (2014) used data from 1979 to 2009 to analyse the inward shift of the Beveridge curve after the reform years and were able to generally confirm the positive effects of the reforms on matching efficiency, although these authors also found that the positive trend of matching efficiency came to an end in 2009. Clearly, these studies have shed light on the temporal and structural properties of the effects of these reforms.

However, until now, it has not been known whether the positive changes in matching efficiency can be observed for all jobs or how the matching efficiencies changed in the relevant partial labour markets and particularly in occupational labour markets. Another relevant question is whether the effects changed temporarily or permanently during (extreme) economic situations, such as the 2008/2009 financial crisis.

This paper complements previous research by estimating the parameters of a macroeconomic matching function on the basis of detailed, high-frequency and more recent administrative data for the 2000–2011 period; thus, it includes the span of the 2008/2009 financial crisis. As this study's first step, I deliver an exact and detailed analysis of the evolution of the matching productivity. Therefore, this study also contributes to the strand of theoretic literature (compare, e.g. with previous studies by Krause and Uhlig, 2012; Krebs and Scheffel, 2013, 2014; Launov and Wälde, 2015) that evaluates further effects of labour market reforms, e.g. on unemployment and others, and refers to the estimated changes in the matching efficiencies (like in Fahr and Sunde 2009; Klinger and Rothe 2012). In the second step, I present an analyses of occupational labour markets because it is known that matching efficiency varies in different occupational labour markets, as shown in Fahr and Sunde (2006); Stops and Mazzoni (2010). To distinguish occupational labour markets, I use the German occupational classification scheme according to Blossfeld (1983). It is possible to identify the temporal evolution of matching productivity by estimating yearly time fixed effects that can be interpreted as year-specific deviations from average matching productivity during the observation period. To identify the temporal evolution of matching productivity in occupational labour markets, I complement the model

with interaction dummy variables that combine yearly and occupational labour market effects.

My analysis corroborates the previous findings of positive changes in the matching productivity during and after all the reform stages and clarifies that there are also positive changes after Hartz IV. Matching productivity hardly increased during the recession in 2009; in specifications without a control for the business cycle, a significant 'crisis' dip is observable. Furthermore, the results reveal positive changes in the matching productivity during and after the reform years in all occupational labour markets. However, the results for the point estimates suggest some differences in more recent changes of matching productivity, but the changes from year to year are not significant.

The remainder of this paper is organised as follows. In Section 2, I describe some relevant facts regarding the German labour market reforms and their (theoretical) implications for matching productivity. Then, I present the theoretical foundations of the macroeconomic matching function, the interpretation of its parameters, and, finally, information about the occupational labour market structure the analysis will be related to. Section 3 presents details about the data used for the analysis and certain descriptive key statistics. Section 4 explains the empirical strategy and reports and discusses estimation results. Robustness checks that generally confirm these results and that are based on both another theoretical perspective of job matching and higher aggregated data are reported in Section 5. Section 6 contains the main conclusions.

2 Labour market reforms and job matching

Empirical findings for the early 2000s in Germany reveal high and persistent unemployment that was independent of the business cycle (Klinger and Rothe 2012). Furthermore, there were discussions regarding opportunities to measure the efforts of public job placement services and to make the job placement organisation more efficient. Therefore, the government stipulated four laws that were implemented in three waves in 2003, 2004 and 2005. In doing so, the government considered the working results of an expert commission, the so-called *Hartz* commission. Each of the *Hartz* I to IV reform laws consisted of various components that refer to the organisation and rules of the labour market. Essentially, three elements of these reforms aimed at an increase of the job-finding rate of unemployed workers: raising the effectiveness and efficiency of the Federal Employment Agency; more activation and higher self-responsibility of the unemployed (principle of 'Promoting and demanding');[2] easing of labour market policy (see for further details, e.g. Bieber et al. 2005; Jacobi and Kluve 2007; Klinger and Rothe 2012; Ochel 2005).

It generally remains an empirical question whether and to what extent all the reform efforts affect labour market outcomes, such as the efficiency of matching. It is not possible to identify the total extent and variation in the described efforts within the different reform stages. Nevertheless, it is possible to evaluate changes in matching productivity before, during and after the reform years with a macroeconomic matching function framework.

The macroeconomic matching function and the matching process behind it were conceived by Diamond (1982a, b); Mortensen (1982); Pissarides (1979, 1985). The matching process begins with the decisions of firms to create a new job or to fill a vacancy (job creation decisions) and decisions of (unemployed) persons regarding how intensely to search for a new job (job search decisions) (Pissarides 2000, p. xi). Firms spend

time, financial and personnel resources for job advertisements, screening, training and vocational adjustments. Job seekers spend resources for job search and application procedures. Unemployed persons and firms are randomly matched and begin to bargain regarding wages.

The basic model assumes homogeneous unemployed persons and homogeneous jobs. The activities of both market sides are matching technologies. The processes behind these activities are not explicitly modelled, so the matching process can be compared with a black box (Petrongolo and Pissarides 2001). The variables U, V and M represent the stock of unemployed, the stock of vacancies and the flows of new hires, respectively. The resulting matching function $f(U, V)$ is specified in a Cobb-Douglas form:

$$M_t = A_t U_t^{\beta_{Us}} V_t^{\beta_{Vs}}, \tag{1}$$

where A describes the 'augmented' matching productivity. Another important assumption lies behind the approach—workers and firms are randomly matched and originate from the pool of existing unemployed workers and job vacancies.

My analysis refers to changes in the parameter A of the matching function that result of changes in the institutional framework of the labour market resulting from the reforms. The central question is whether this parameter changed after implementing the reforms. Therefore, I assume that this parameter varies over time; thus, A_t is different for different observation periods, whereas the elasticities remain constant during the entire observation period.

This model differs from Klinger and Rothe (2012) and Fahr and Sunde (2009), who both assumed that there is a constant augmented productivity for the observation period before the reforms were implemented and a (possibly) different augmented productivity after the reform was introduced.[3] In the model described above, this term differs from observation period to observation period. Therefore, it is possible to compare the temporal evolution of augmented productivity, which is similar to Klinger and Weber (2014), who estimate an 'extended matching function' that contains a time-varying matching efficiency parameter that is decomposed in a cyclical and a trend component. However, their identification strategy differs from the strategy utilised herein because it is based on a multivariate time series and correlated unobserved components model, whereas the identification made in this paper is based on variations in repeated observations in regional and occupational labour markets.

To analyse the reforms' effects on occupational labour markets, I use the occupational classification scheme derived by Blossfeld (1983), who divides the labour market into 12 broader occupational categories and a category '[0] Not assignable' (Table 1). These categories can be roughly assigned to qualification levels and sectors. Thus, this classification can be understood as an approximation of occupational labour markets that are assumed to be separate from one another and as a good (exogenous) base for the analysis of changes in the matching efficiency of occupational labour markets.

Again, I assume constant matching elasticities of unemployed and vacancies (stocks and flows) in the economy, but the augmented productivity term A_{tb} now varies with the occupational categories b and observation periods t:

$$M_{tb} = A_{tb} U_{tb}^{\beta_{Us}} V_{tb}^{\beta_{Vs}} \tag{2}$$

Table 1 Occupational categories

[1]	AGR agrarian occupations
[2]	EMB simple manual occupations
[3]	QMB qualified manual occupations
[4]	TEC technicians
[5]	ING engineers
[6]	EDI simple service occupations
[7]	QDI qualified service occupations
[8]	SEMI semi-professions
[9]	PROF professions
[10]	EVB simple business and administrative occupations
[11]	QVB qualified business and administrative occupations
[12]	MAN manager
[0]	*Not assignable*

Source: Occupational categories are taken from Blossfeld (1983)

3 Data

I use a unique administrative panel data set of 329 occupational orders in 402 NUTS3 regions with 138 observation periods from January 2000 to June 2011. The occupational orders are coded according to the German occupational classification scheme (three digits, Kldb88).[4] All the data stem from the Federal Employment Agency. The groups are assigned to the 13 occupational labour markets described in the previous section.[5]

I use monthly data regarding flows from unemployment to employment and stocks of unemployed and registered vacancies. Table 2 shows some descriptive statistics.

To get unbiased matching parameter estimations, I adjust the data set by observations for occupations and NUTS3 regions, respectively, in which vacancies, unemployed or flows into employment are reported as zero, which leads to an unbalanced panel data structure with about 2.394 million observations.

Previous literature reported several concerns regarding the vacancy and the unemployment series that should be borne in mind. The first concern is about the time series of vacancies. According to Fahr and Sunde (2009), the time series before 2001 reveal a certain lack of information about the region where the vacancy is situated. However, this is true for 'only a few' NUTS3 regions (Bundesagentur für Arbeit 2016) and the cleansing procedure, described above, also accounts for that. In addition, the time series of the vacancy statistics were further improved in July 2010 and recomputed again until January 2000 (Hartmann and Reimer 2010). Therefore, the values from different months within the chosen observation period from January 2000 to June 2011 should be better comparable than before this revision in 2010.

Table 2 Descriptive statistics

Measure	Monthly averages 2000–2011 (in 1000)			
	Mean	Minimum	Maximum	Standard deviation
Employment inflows *M*	259	144	412	51
Unemployment stock *U*	3750	2761	4950	570
Registered vacancies stock *V*	332	173	460	79

Source: Own calculation based on the administrative data from the statistics department of the Federal Employment Agency 2000–2011

The time series for the unemployed are also improved since the mentioned studies were published. However, regarding the statistics of recipients of the means tested unemployment benefits II (UB II, 'Arbeitslosengeld II') in the years 2005 and 2006, it cannot be ruled out that some of the recipients are recorded two times in case unemployed persons changed the provider of the UB II. Only a small part of the recipients of means tested unemployment benefits were affected by this, e.g. an analysis of the effect of the revision showed that the stocks of unemployed changed less than one permille compared to the previous statistics and there are only a few NUTS3 regions where the changes are more important regarding (only) the inflows in employment (Bundesagentur für Arbeit 2015; Engelhardt et al. 2014). An other concern raised by Fahr and Sunde (2009) was that the definition of unemployment changed in January 2005 with the result that the number of unemployed increased due to statistical reasons.[6] Klinger and Rothe (2012) suggests to control for the observation periods when the change happened by including a dummy for the first quarter in 2015 in their empirical model. The analysis here is based on monthly or yearly time effects. According to the results in Klinger and Rothe (2012), this would imply that the 'break' in January 2005 could affect the monthly effects of the first quarter and the year effect of 2005.

Figure 1 shows the time series of unemployment stocks, unemployment inflows, vacancy stocks, vacancy inflows and flows from unemployment into employment and their trends. The trends are computed using the Hodrick Prescott filter (Hodrick and Prescott 1997). It is clear that there is a change in the trends from 2003 to 2005, i.e., the reform years. Whereas the trends of the unemployment outflows and inflows and the stocks of registered vacancies decreased before and increased after the reform years, the stock and inflows of the unemployed increased before and decreased after the reform years. However, the strongest changes are shown in the unemployment and the vacancy stocks, whereas the outflows reveal only slight changes in the trend.

4 Empirical strategy and results

4.1 Aggregated estimations

At first, I estimate regression equations that are based on the logarithm version of Eq. (1) and complemented by further variables that are included stepwise:

$$\log M_{ijt} = a+\beta_{Us}\log U_{ijt}+\beta_{Vs}\log V_{ijt}+\mu_{ij}+\theta\mathbf{X}_{ijt}+\gamma\mathrm{GDP}_{\mathrm{cyc,FS}}(i),\mathrm{year}(t)+d_t+\epsilon_{ijt} \quad (3)$$

Here, the term $\log M_{ijt}$ denotes the logarithm of the flows from unemployment to employment for region i, occupational order j and observation period t. The parameter a is a constant and thus a component of the logarithm of the average augmented matching productivity. The variables $\log U$ and $\log V$ are the logarithms of the unemployed and vacancy stocks, whereas β_{Us} and β_{Vs} denote the matching elasticities of the unemployed and vacancies, respectively. The column vector $\mathbf{X}$ contains a set of four control variables in its columns: the share of female employees on all employees subject to social security contributions and two variables with the shares of employees with 'vocational training' and the shares of employees with an 'academic degree' (with reference group 'without occupational training'). These variables are based on data for the occupational orders and the NUTS 3 regions. The fourth variable contains the average age of the population in each NUTS 3 region. These four variables are included in all specifications to control for some developments in the (working) population that could also potentially have an impact on

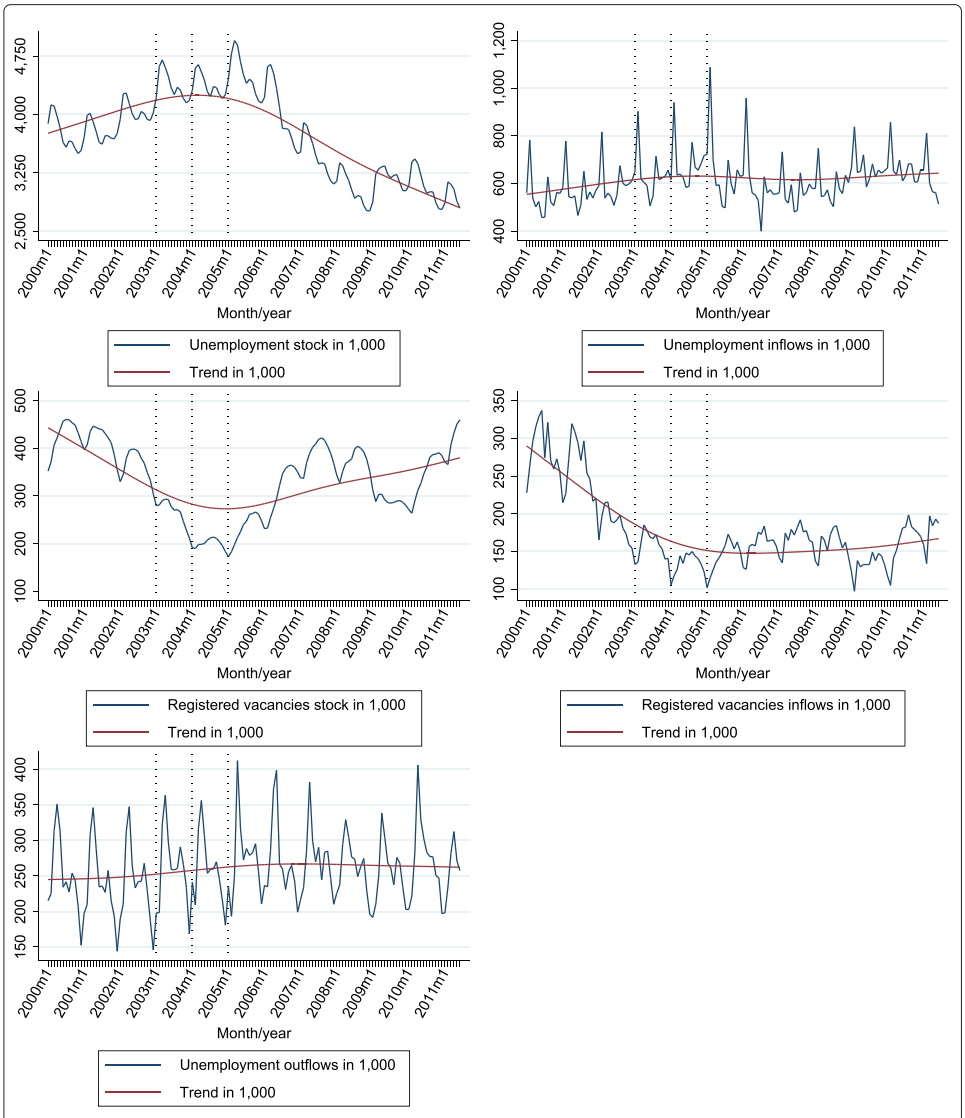

Fig. 1 Time series of the key figures for the 2000–2011 analysis. Source: Statistics of the Federal Employment Agency, own computations. Trends are computed with the Hodrick Prescott filter (Hodrick and Prescott 1997) with smoothing parameter $\alpha = 129,600$ (according to Ravn and Uhlig 2002)

the development of the matching efficiency.[7] The row vector θ contains the coefficients of these control variables. Furthermore, the regression equation contains a fixed effect, μ_{ij}, for each regional occupational labour market, ij, that can be interpreted as the occupational and local area specific augmented productivity. Finally, this basic specification includes also an i.i.d. error term, ϵ_{ijt}, for each observation.

In the next step, I include the cyclical component of real gross domestic product, $\text{GDP}_{\text{cyc,FS}(i),\text{year}(t)}$, for the federal state, FS, that region i belongs to and the year that the observation period, t, belongs to. The coefficient for this variable is γ. Then, I include monthly time fixed effects, d_t, that are—for the moment—the coefficients of interest. These variables are effect coded, and their coefficients can thus be directly interpreted as the monthly deviations from the average augmented matching productivity for the 2000 to 2011 observation period.[8] The reference period is January 2000.

Finally, I modify the regression above by including dummy variables $d_q(t)$ for the first, second, or third quarter of the year. Furthermore, I substitute the monthly observation period time fixed effects with year fixed effects $d_{\text{year}(t)}$. This variable is also effect coded,[9] and the reference year is 2000. Thus, the latter variable can be interpreted as the yearly seasonal adjusted deviation from the average of augmented matching productivity during the 2001 to 2011 observation period. The regression equation is then as follows:

$$\log M_{ijt} = a + \beta_{Us} \log U_{ijt} + \beta_{Vs} \log V_{ijt} + \theta \mathbf{X}_{ijt} + \gamma \text{GDP}_{\text{cyc,FS}(i),\text{year}(t)} + \cdots \\ \cdots + d_{q(t)} + d_{\text{year}(t)} + \mu_{ij} + \epsilon_{ijt} \tag{4}$$

In panel data sets like the one I utilised here, cross-sectional dependence cannot generally be ruled out. To get further indications whether cross-sectional dependence has to be considered, I calculated Pesaran's CD statistic. This statistic is the basis for a test for cross-sectional dependence in the residuals (Pesaran (2004)). The results reveal that the Null of strong cross-sectional dependence in the residuals cannot be rejected.[10] Furthermore, another issue of panel data sets could be temporal autocorrelation of the residuals and heteroscedastic error terms. Therefore, I calculated Driscoll-Kraay standard errors that account for general forms of spatial and temporal dependence and heteroscedaticity in case of a relative large time dimension and a quite larger number of cross-sectional units (Driscoll and Kraay 1998).[11]

The results of the estimations can be found in Table 3. Column FE 1 of Table 3 refers to the basic specification. As expected from the theoretical model, the matching elasticities of the unemployed and vacancy stocks are both significantly positive. Furthermore, the matching elasticity of the unemployed is higher than the matching elasticity of the vacancies; this result corroborates previous studies for Germany (Burda and Wyplosz, 1994; Entorf, 1998; Fahr and Sunde, 2004; Klinger and Rothe, 2012; Stops and Mazzoni, 2010).

The results in the second column, FE 2, belong to the same specification augmented with the cyclical component of the yearly gross domestic product for the 16 federal states ($\text{GDP}_{\text{cyc,FS}(i),\text{year}(t)}$). These results do not differ much from the results in the first column, FE 1.

The third column, FE 3, contains the results for the regression Eq. (3), including monthly time fixed effects. Compared with previous specifications, the matching elasticities of the unemployed are somewhat higher and the matching elasticities of the vacancies are lower. The monthly fixed effects are not presented in Table 3; however, their graphical representation can be found in the left panel of Fig. 2. The right panel of this figure shows the evolution of the year fixed effects of column 4 in Table 3.

As explained above, these variables can be interpreted as time-specific deviations from the average augmented matching productivity, where the average is normalised to zero. Accordingly, from the beginning of the observation period until 2006, the monthly deviations might be negative or positive with a seasonal pattern. In addition, beginning with the reform years, 2003–2005, and continuing forward, the monthly deviations began to increase from year to year; from 2007 onwards, the deviations are all significantly positive. These results provide the first impression of how augmented matching productivity developed after the labour market reforms were implemented in 2003 to 2005. All in all, the volatile seasonal pattern gives only a rough first impression regarding the evolution of matching productivity.

Table 3 Fixed effects estimation results based on the data set disaggregated by occupations and NUTS3 regions

	Dependent variable: log *M*			
	FE 1	FE 2	FE 3	FE 4
β_{Us}	0.580***	0.592***	0.624***	0.626***
	(0.013)	(0.012)	(0.009)	(0.010)
β_{Vs}	0.065***	0.058***	0.039***	0.044***
	(0.006)	(0.005)	(0.004)	(0.004)
Year dummies, effect coded (reference year: 2000):				
d_{2001}				−0.116***
				(0.031)
d_{2002}				−0.149***
				(0.026)
d_{2003}				−0.122***
				(0.017)
d_{2004}				−0.111***
				(0.019)
d_{2005}				−0.082***
				(0.022)
d_{2006}				−0.030**
				(0.014)
d_{2007}				0.066***
				(0.020)
d_{2008}				0.143***
				(0.015)
d_{2009}				0.146***
				(0.017)
d_{2010}				0.178***
				(0.021)
d_{2011}				0.152***
				(0.020)
γ		1.681***	1.363***	1.377***
		(0.557)	(0.272)	(0.271)
a	−4.533***	−4.785***	−0.896**	−0.826**
	(0.633)	(0.614)	(0.397)	(0.410)
Control variables	Yes	Yes	Yes	Yes
Monthly time dummies	No	No	Yes	No
Quarter dummies	No	No	No	Yes
Observations	2,393,683	2,393,683	2,393,683	2,393,683
Number of groups	55,316	55,316	55,316	55,316
Within R-squared	0.236	0.240	0.304	0.275

Driscoll-Kraay standard errors in parentheses. Column FE 3 includes monthly time fixed effects with effect coding (reference period is January 2000); compare with Fig. 2, left panel. Control variables are the share of female workers, the shares of workers at different skill levels ('vocational training' and 'academic degree,' reference group is 'without vocational training') in each NUTS3 region and occupation, and the average age by the population by NUTS3 regions. The estimated coefficients are provided on request. The estimated coefficients are provided on request

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

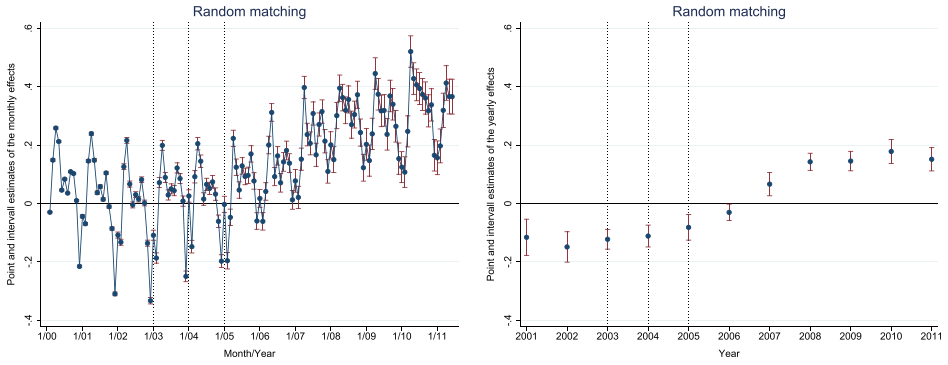

Fig. 2 Month and year time fixed effects and 95 % confidence band. Notes: Specifications from Table 3, *left side*, are FE 3; those from the *right side* are FE 4—based on a data set disaggregated by occupations and NUTS3 regions. The *blue dots* and the *vertical red lines* mark the point and 95 % interval estimates, and the interval is very small in some cases. In the *left panel*, the dots are linked with a line to illustrate temporal development. Time fixed effects with effect coding (the reference period is January 2000 for month fixed effects or 2000 for year fixed effects, respectively)

In Eq. (4), the year dummies can be interpreted as yearly deviations from the averaged augmented matching productivity and should thus give a clearer picture. Furthermore, seasonality patterns are adjusted by quarter dummies. The results of the estimations, including the yearly deviations, are reported in column 4 of Table 3. The graphical representation of the year effects for the random matching model can be found in the right panel of Fig. 2.

The yearly deviations are negative at the beginning of the observation period and begin to increase from 2002; they become significantly positive from 2007 onwards. There is hardly an increase in 2009, the year of the financial crisis, and after a further small increase in 2010, the deviation slightly decreases in 2011. The changes are small, but one can observe a significant 'crisis dip' in 2009 and larger elasticity and productivity coefficients based on regression equations without the business cycle variable, $\mathrm{GDP}_{\mathrm{cyc,FS}(i),\mathrm{year}(t)}$, as a control variable; compare with columns 1 to 3 of Table 9 and the left panels of Figs. 9 and 10 in 'Further results' in the Appendix.

In general, it can be concluded from the results that there are positive changes in matching productivity during and after implementation of the reform; in recent years, there are only small changes. Therefore, the results are in line with the previous studies regarding the development of the matching efficiency after 2003 and 2004 (part. Fahr and Sunde 2009; Klinger and Rothe 2012; Klinger and Weber 2014). The results are different to Klinger and Rothe (2012) who did not find further increases after 2005. However, Klinger and Weber (2014) and this study found that the matching efficiency further increased in the following years.

For interpretation of the results, one should consider that the estimated time fixed effects are only the part of the augmented matching productivity parameter $\log A$ that is not explained by the business cycle, the information in the controls and the regional fixed effects. To get a more comprehensive view of the development of the matching efficiency, I calculated predictions of $\log A$ (and A), based on specifications including the business cycle variable and without. The computations of both specification are very similar and they show again clearly the 'crisis' dip, higher increases in the matching efficiency after the

reform years than before, the same lower increases in recent year, including 2011. More details can be found in 'Predicted matching efficiencies' in the Appendix.

4.2 Occupational labour markets

Figure 3 describes the development of the trends of our key figures—flows from unemployment to employment, unemployment stocks, and the registered vacancy stocks—as normalised measures with index 1 first in January 2000 (left panels) and second for January 2005 (right panels).

Generally, these figures show that there is a certain heterogeneity in the development of the key figures in different occupational labour markets, which leads me to the conclusion that I can expect different results regarding the analysis of the changes of the matching elasticity in these markets. Thus, I separately estimate the deviations of the averaged augmented productivity for the occupational labour markets, $b(j)$, that the occupational order j is assigned to. The regression is equivalent to the logarithm version of Eq. (2). Again, this specification is stepwise complemented by additional variables:

$$\log M_{ijt} = a + \beta_{Us} \log U_{ijt} + \beta_{Vs} \log V_{ijt} + \theta \mathbf{X}_{ijt} + \mathrm{GDP}_{\mathrm{cyc,FS}(i),\mathrm{year}(t)} + \cdots \\ \cdots + d_i + d_{q(t)} + d_{\mathrm{year}(t)} + d_{b(j)} + d_{b(j),\mathrm{year}(t)} + \epsilon_{ijt} \tag{5}$$

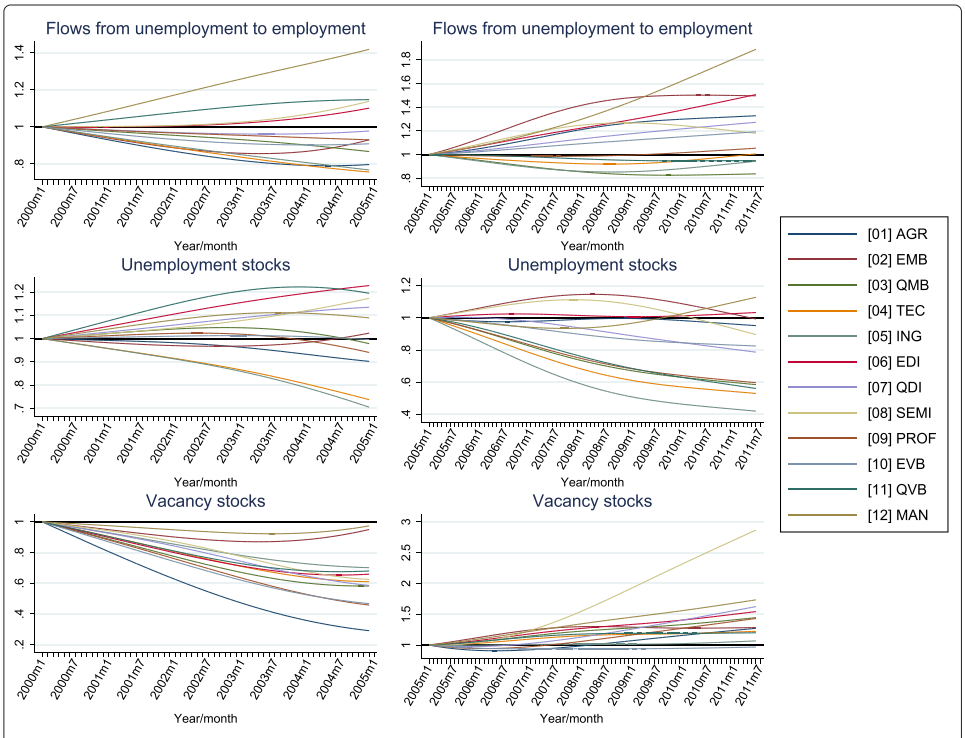

Fig. 3 Key figures by occupational groups, normalised trends, 2000–2004 (January 2000 = 1, *left panel*) and 2005–2011 (January 2005=1, *right panel*). Source: Statistics of the Federal Employment Agency. Trends are computed with the Hodrick Prescott filter (Hodrick and Prescott 1997) with smoothing parameter α = 129,600 (according to Ravn and Uhlig 2002). *[01] AGR* agrarian occupations, *[02] EMB* simple manual occupations, *[03] QMB* qualified manual occupations, *[04] TEC* technicians, *[05] ING* engineers, *[06] EDI* simple service occupations, *[07] QDI* qualified service occupations, *[08] SEMI* semi professions, *[09] PROF* professions, *[10] EVB* simple business and administrative occupations, *[11] QVB* qualified business and administrative occupations, *[12] MAN* manager

Here, it is not possible to separate the occupational and regional fixed effects and the occupational labour market effects, $b(j)$, related to occupation j. Therefore, I exclude the fixed effects μ_{ij} and I estimate an ordinary least squares (OLS) model. The model is augmented by local area effects d_i, quarter dummy variables ($d_{q(t)}$) and year dummies (yearly observation period fixed effects, $d_{\text{year}(t)}$) with reference to year 2000 and thus the yearly specific deviations from the average augmented productivity. Furthermore, it contains dummy variables for 11 occupational categories with reference to the 'agrarian and not assignable occupations' ($d_{b(j)}$) categories. The coefficients of these variables are equivalent to the occupational labour market's specific deviations from average matching productivity. Finally, the model contains interaction dummies for the yearly and occupational labour market–specific deviations $d_{b(j),\text{year}(t)}$. Formally, the latter variable is the interaction term of the year dummies and the occupational labour market dummy variables. Again, dummy variables are effect coded with the exception of the quarter dummy (the fourth quarter is the reference period).

The results can be found in Table 4. Column OLS 1 contains the OLS estimation of a pure matching model without the business cycle variable or further dummy variables. As expected, the coefficients for the matching elasticities are again significantly positive. After including the business cycle variable (OLS 2), the coefficients hardly change. Column OLS 3 of Table 4 shows the results for the specifications, including dummy variables for year effects, quarters and occupational labour markets. In particular, the year fixed effects coefficients have a similar pattern as the results of the fixed effects estimations. Thus, the main conclusions of the previous section are unaffected. Finally, column OLS 4 reports the results of the full specification, including year- and occupational-specific interaction effects. Due to space constraints, I do not report the latter coefficients, but I show the point and interval estimations graphically in Figs. 4 and 5.

Columns OLS 3 and OLS 4 reveal another finding: at the 5 % level, the occupational labour market specific deviations from the augmented productivity for the observation period are significantly negative for occupations that are assignable to a lower skill level (EMB, EDI, EVB) and for technicians (TEC) and engineers (ING). The deviations of qualified business and administrative occupations (QVB) and qualified service occupations (QDI) are insignificant, and the deviations of the remaining occupational categories are significantly positive.

In the following, I discuss the results for the year- and occupational-specific interaction effects. Figures 4 and 5 show 95 % interval estimate sums of the yearly dummy and the yearly interaction effects dummy variables in 11 panels for each occupational labour market ($d_{\text{year}(t)} + d_{b(j),\text{year}(t)}$), with the exception of the reference category '[AGR] agrarian and not assignable occupations'). These sums represent the yearly deviations from average occupational labour market-specific augmented productivity ($d_{b(j)}$); thus, they show how the augmented productivity in a certain occupational labour market is changed based on a 'pure' time effect.

The common finding is that there is a positive change in the deviation from occupational labour market-specific augmented productivity after the reform years, which can be understood as an indicator that the reform had effects on the entire labour market. However, there are certain differences regarding the timing of the change and the further development of matching efficiency. In addition, differences arise during the years of the financial crisis in 2008/2009.

Table 4 OLS estimation results based on data set disaggregated by occupations and NUTS3 regions

	Dependent variable: log *M*			
	OLS 1	OLS 2	OLS 3	OLS 4
β_{Us}	0.631***	0.635***	0.662***	0.662***
	(0.006)	(0.006)	(0.007)	(0.006)
β_{Vs}	0.127***	0.123***	0.114***	0.115***
	(0.004)	(0.004)	(0.004)	(0.004)
Year dummies, effect coded (reference year: 2000):				
d_{2001}			−0.121***	−0.131***
			(0.031)	(0.028)
d_{2002}			−0.151***	−0.157***
			(0.026)	(0.025)
d_{2003}			−0.112***	−0.124***
			(0.018)	(0.020)
d_{2004}			−0.085***	−0.087***
			(0.018)	(0.020)
d_{2005}			−0.065***	−0.059***
			(0.021)	(0.022)
d_{2006}			−0.030**	−0.035*
			(0.013)	(0.018)
d_{2007}			0.053**	0.066***
			(0.021)	(0.024)
d_{2008}			0.133***	0.148***
			(0.015)	(0.018)
d_{2009}			0.156***	0.174***
			(0.017)	(0.017)
d_{2010}			0.169***	0.170***
			(0.020)	(0.017)
d_{2011}			0.130***	0.137***
			(0.022)	(0.028)
Dummies for occupational categories, effect coded (reference: [0]/[1] AGR)				
[02] EMB			-0.016	-0.020**
			(0.011)	(0.010)
[03] QMB			0.056***	0.054***
			(0.013)	(0.008)
[04] TEC			−0.096***	−0.093***
			(0.006)	(0.005)
[05] ING			−0.100***	−0.085***
			(0.016)	(0.010)
[06] EDI			−0.102***	−0.104***
			(0.009)	(0.007)
[07] QDI			0.080***	0.078***
			(0.008)	(0.007)
[08] SEMI			0.095***	0.093***
			(0.014)	(0.013)
[09] PROF			0.271***	0.281***
			(0.014)	(0.011)
[10] EVB			−0.212***	−0.212***
			(0.007)	(0.007)
[11] QVB			−0.043***	−0.043***
			(0.007)	(0.007)
[12] MAN			0.005	0.003

Table 4 OLS estimation results based on data set disaggregated by occupations and NUTS3 regions (*Continued*)

	Dependent variable: log *M*			
	OLS 1	OLS 2	OLS 3	OLS 4
			(0.009)	(0.007)
γ		1.492**	1.559***	1.504***
		(0.582)	(0.269)	(0.264)
a	−5.091***	−5.233***	−1.605***	−1.753***
	(0.617)	(0.593)	(0.438)	(0.404)
Control variables	Yes	Yes	Yes	Yes
Local area effects	Yes	Yes	Yes	Yes
Occupational yearly interaction effects	No	No	No	Yes
Quarter dummies	No	No	Yes	Yes
Observations	2,393,683	2,393,683	2,393,683	2,393,683
R-squared	0.711	0.712	0.730	0.731

Driscoll-Kraay standard errors in parentheses. Columns OLS 4 includes yearly time and occupational category interaction effects (reference year is 2000, reference category is '[01] AGR Agrarian and not assignable occupations'), and all dummy variables are effect coded; compare 'Effect coding' in the Appendix. Control variables are the share of female workers, the shares of workers at different skill levels ('vocational training' and 'academic degree,' reference group is 'without vocational training') in each NUTS3 region and occupation, and the average age by the population by NUTS3 regions. The estimated coefficients are provided on request.

[01] AGR agrarian and not assignable occupations, *[02] EMB* simple manual occupations, *[03] QMB* qualified manual occupations, *[04] TEC* technicians, *[05] ING* engineers, *[06] EDI* simple service occupations, *[07] QDI* qualified service occupations, *[08] SEMI* semi professions, *[09] PROF* professions, *[10] EVB* simple business and administrative occupations, *[11] QVB* qualified business and administrative occupations, and *[12] MAN* manager

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Regarding the structure of the time effects after the crisis, there are significantly positive effects observable from 2008 onwards, at the latest. Information regarding the timing of the effects complements previous studies that only compared matching productivity before or during the reform years and after the reform years (part., Fahr and Sunde 2009; Klinger and Rothe 2012) and also illustrates that it is hardly possible to distinguish between the effects of the different reform stages because it would imply that the consequences of each reform stage came into effect within 1 year.[12] This result can hardly be corroborated based on the results in this study.[13] Overall, the view on the year effects in the different occupational labour markets confirm the finding that the development of the matching efficiency is rather different in different occupational labour markets; thus, the timing of the effects is also different.

Regarding the further evolution of the time fixed effects, the results reveal that the point estimates of the effects differ between the occupational labour markets in recent years. For example, with the exception of technicians (TEC) and engineers (ING), the positive deviations decreased in at least the last years, i.e. from 2009 to 2011. However, the changes from year to year are not significant.

5 Validity and robustness checks

5.1 Another theoretical perspective: selective search

Gregg and Petrongolo (2005) state that the unstable results of papers that study the parameters of matching functions result in a certain misspecification of the matching function due to the assumption of (completely) random search. These authors propose to utilise a stock-flow matching model framework, originally derived by Coles (1994) and

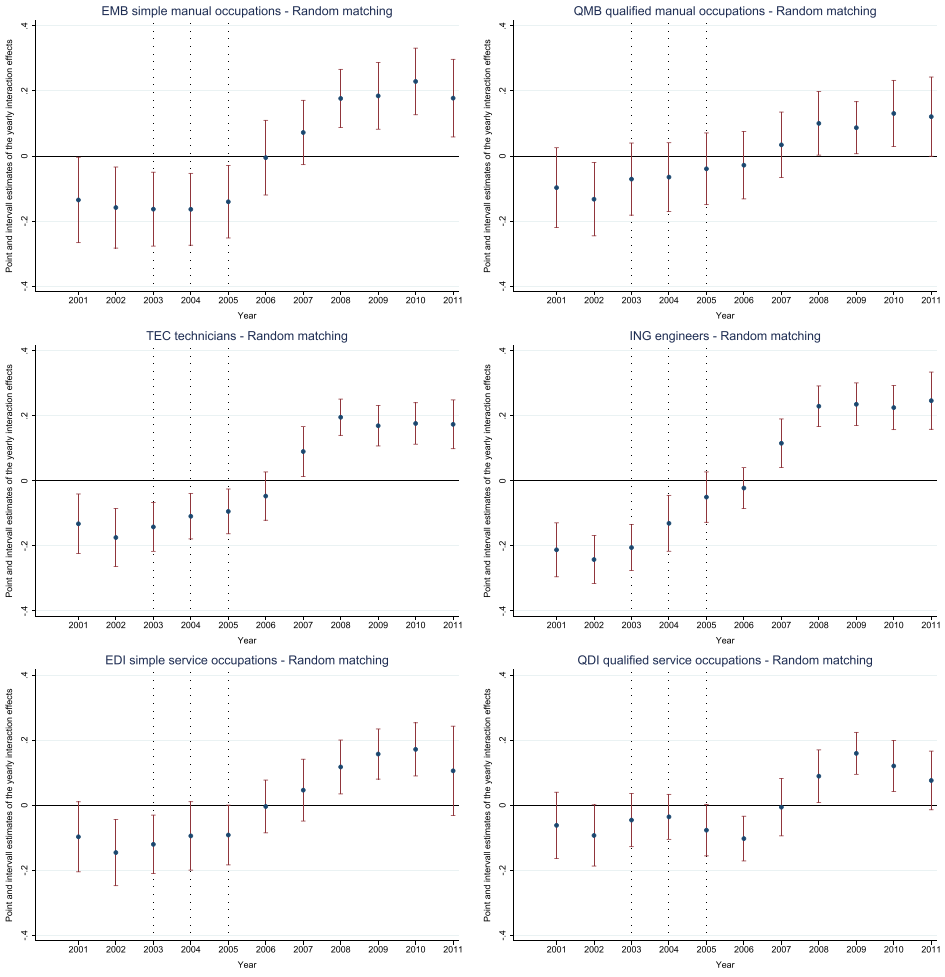

Fig. 4 Estimated sums of the yearly dummy and the yearly interaction effects and 95 % confidence band by occupational categories (part 1/2). Source: Statistics of the Federal Employment Agency, own computations. Notes: The graphs refer to the results in column OLS 4 in Table 4, based on a data set disaggregated by occupations and NUTS3 regions. The *blue dots* and the *vertical red lines* mark the point and 95 % interval estimates

Coles and Smith (1998). This approach considers job searching that is not completely random. However, for this, it must state an assumption that might be understood as a further restriction of the random matching approach: the assumption is made that the agents on both sides of the market are able to sample the entire relevant part of the stocks of the other side with no friction due to the availability of quite efficient information channels. Following that, the agents who did not found adequate offers and, therefore, remain in the unemployed or vacancy stocks, respectively, only select further offers on the other market side from those that have just arrived. However, Gregg and Petrongolo (2005) concluded that the true (single) matching process is equivalent to one that is somewhere between the random matching approach and the stock-flow matching approach. Whereas random matching assumes a search process that consumes time to sample and assess all available and relevant (stocks of) offers from the other market side, the stock-flow matching approach is assumed to minimise the required time to check the stocks of the other

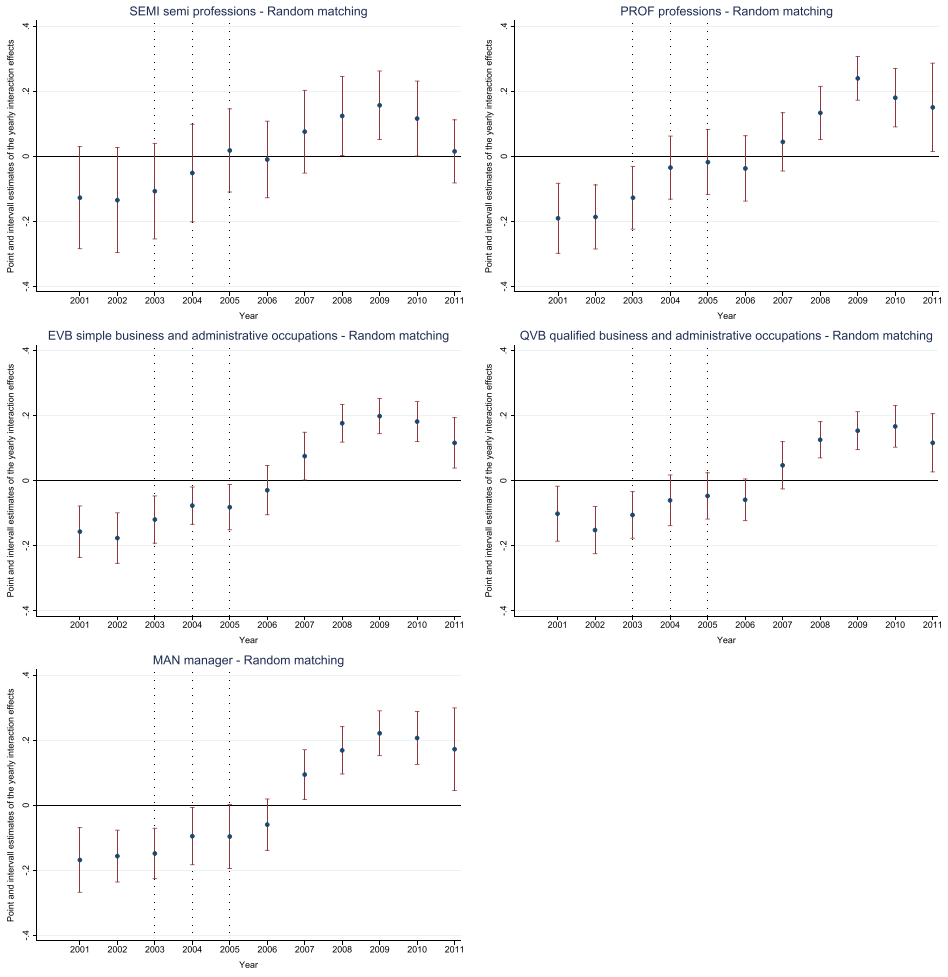

Fig. 5 Estimated sums of the yearly dummy and the yearly interaction effects and 95 % confidence band by occupational categories (part 2/2). Source: Statistics of the Federal Employment Agency, own computations. Notes: Graphs refer to results in column OLS 4 in Table 4, based on the data set disaggregated by occupations and NUTS3 regions. The *blue dots* and the *vertical red lines* mark the point and 95 % interval estimates

market side to zero. These concepts offer me a good opportunity to discuss the robustness of the focussed efficiency parameter estimates on the basis of two different matching functions.

Therefore, the matches are determined, on the one hand, by the stocks of the unemployed and the inflows of vacancies and, on the other hand, by the stocks of vacancies and the inflows of the unemployed. Technically, the matching function in Eq. (1) is complemented by the inflows of the unemployed u and vacancies v with their matching elasticities β_{Uf} and β_{Vf}:

Table 5 (Additional) descriptive statistics

Measure	Monthly averages 2000–2011 (in 1000)			
	Mean	Minimum	Maximum	Standard deviation
Unemployment inflows *u*	616	400	1088	101
Registered vacancies inflows *v*	177	97	337	52

Source: Own calculation based on the administrative data from the statistics department of the Federal Employment Agency 2000–2011

Table 6 Robustness check: fixed effects estimation results based on the stock-flow matching model and data set disaggregated by occupations and NUTS3 regions

	Dependent variable: log *M*			
	FE 1	FE 2	FE 3	FE 4
β_{Us}	0.543***	0.554***	0.565***	0.583***
	(0.016)	(0.016)	(0.013)	(0.013)
β_{Uf}	0.044***	0.047***	0.071***	0.049***
	(0.014)	(0.014)	(0.009)	(0.011)
β_{Vs}	0.036***	0.029***	0.020***	0.022***
	(0.005)	(0.004)	(0.003)	(0.003)
β_{Vf}	0.044***	0.044***	0.031***	0.035***
	(0.007)	(0.007)	(0.004)	(0.004)
Year dummies, effect coded (reference year: 2000):				
d_{2001}				−0.116***
				(0.030)
d_{2002}				−0.141***
				(0.026)
d_{2003}				−0.115***
				(0.017)
d_{2004}				−0.109***
				(0.019)
d_{2005}				−0.074***
				(0.022)
d_{2006}				−0.023
				(0.015)
d_{2007}				0.068***
				(0.020)
d_{2008}				0.136***
				(0.015)
d_{2009}				0.140***
				(0.017)
d_{2010}				0.168***
				(0.020)
d_{2011}				0.142***
				(0.020)
γ		1.712***	1.400***	1.433***
		(0.543)	(0.271)	(0.270)
a	−4.449***	−4.694***	−0.829**	−0.812*
	(0.609)	(0.590)	(0.399)	(0.412)
Control variables	Yes	Yes	Yes	Yes
Monthly time dummies	No	No	Yes	No
Quarter dummies	No	No	No	Yes
Observations	2,393,683	2,393,683	2,393,683	2,393,683
Number of groups	55,316	55,316	55,316	55,316
Within R-squared	0.241	0.245	0.309	0.279

Driscoll-Kraay standard errors in parentheses. Column FE 3 includes monthly time fixed effects with effect coding (reference period is January 2000), compared with Fig. 6, left panel. Control variables are the share of female workers, the shares of workers at different skill levels ('vocational training' and 'academic degree,' reference group is 'without vocational training') in each NUTS3 region and occupation and the average age by the population by NUTS3 regions. The estimated coefficients are provided on request

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

$$M_t = A_t U_t^{\beta_{Us}} u_t^{\beta_{Uf}} V_t^{\beta_{Vs}} v_t^{\beta_{Vf}} \tag{6}$$

The model that considers the variation of the augmented productivity term with occupational labour markets b, compared with Eq. (2), is then modified to:

$$M_{tb} = A_{tb} U_{tb}^{\beta_{Us}} u_{tb}^{\beta_{Uf}} V_t^{\beta_{Vs}} v_{tb}^{\beta_{Vf}} \tag{7}$$

Table 5 shows some descriptive statistics for the aggregated flows from the data set.

The logarithm versions of the stock-flow models are equivalent to the regression Eqs. (3) and (4) for the random matching model complemented by parameters and variables of the logarithm of the flow measures:

$$\log M_{ijt} = [\textit{Right side of Eq. (3) or (4)}] + \beta_{Uf} \log u_{ijt} + \beta_{Vf} \log v_{ijt} \tag{8}$$

Thus, the variables $\log u$ and $\log v$ are the logarithms of the unemployed and vacancy inflows whereas β_{Uf} and β_{Vf} denote the matching elasticities of the inflows of the unemployed and vacancies, respectively.

The results of the estimations of the stock-flow matching parameters can be found in Table 6. Compared with Table 3, the columns contain the results of the same specifications augmented with the inflow measures for registered vacancies and the unemployed. The graphic representation for the month fixed effects (FE 3) and year fixed effects (FE 4) can be found in Fig. 6. Overall, the results do not reveal fundamental differences with those that are based on the random matching approach.

The foregoing is also true for the regressions' estimates without the business cycle variable, compared with columns 4 to 6 of Table 9 in the Appendix and the right panels of

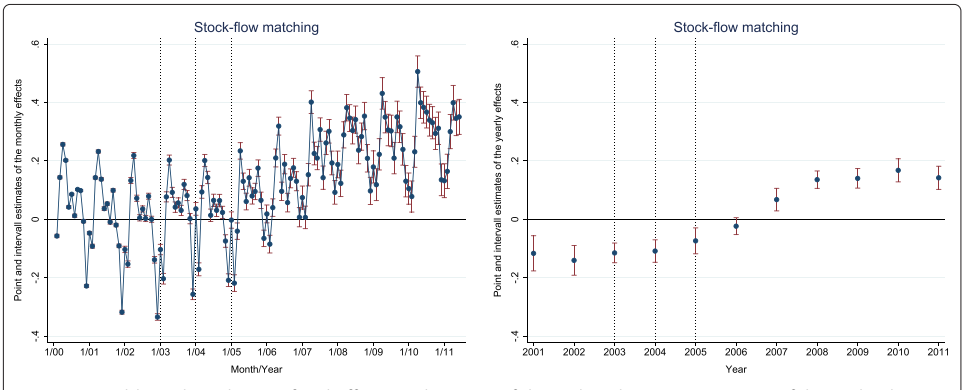

Fig. 6 Monthly and yearly time fixed effects and 95 % confidence band. Source: Statistics of the Federal Employment Agency, own computations. Notes: Specifications from Table 6, *left side* FE 3, *right side* FE 4, based on the data set disaggregated by occupations and NUTS3 regions. The *blue dots* and the *vertical red lines* mark the point and 95 % interval estimates; the interval is very small in some cases. In the left panel, the dots are linked with a line to illustrate temporal development. Time fixed effects with effect coding (reference period is January 2000 for month or year 2000 for year fixed effects)

Table 7 Robustness check: OLS estimation results based on stock-flow matching model and data set disaggregated by occupations and NUTS3 regions

	Dependent variable: log *M*			
	OLS 1	OLS 2	OLS 3	OLS 4
β_{Us}	0.441***	0.443***	0.478***	0.479***
	(0.014)	(0.014)	(0.012)	(0.012)
β_{Uf}	0.192***	0.194***	0.182***	0.180***
	(0.012)	(0.012)	(0.010)	(0.010)
β_{Vs}	0.043***	0.039***	0.043***	0.043***
	(0.005)	(0.004)	(0.003)	(0.003)
β_{Vf}	0.094***	0.093***	0.082***	0.083***
	(0.008)	(0.007)	(0.006)	(0.005)
Year dummies, effect coded (reference year: 2000):				
d_{2001}			-0.114***	-0.122***
			(0.029)	(0.027)
d_{2002}			-0.122***	-0.129***
			(0.025)	(0.024)
d_{2003}			-0.086***	-0.099***
			(0.018)	(0.021)
d_{2004}			-0.078***	-0.080***
			(0.020)	(0.022)
d_{2005}			-0.036	-0.035
			(0.023)	(0.022)
d_{2006}			-0.004	-0.012
			(0.015)	(0.016)
d_{2007}			0.057***	0.068***
			(0.019)	(0.022)
d_{2008}			0.103***	0.117***
			(0.016)	(0.019)
d_{2009}			0.123***	0.139***
			(0.018)	(0.018)
d_{2010}			0.130***	0.134***
			(0.019)	(0.018)
d_{2011}			0.096***	0.106***
			(0.022)	(0.027)
Dummies for occupational categories, effect coded (reference: [0]/[1] AGR)				
[02] EMB			-0.020**	-0.024**
			(0.010)	(0.010)
[03] QMB			0.028**	0.026***
			(0.011)	(0.007)
[04] TEC			-0.070***	-0.069***
			(0.007)	(0.006)
[05] ING			-0.091***	-0.078***
			(0.014)	(0.008)
[06] EDI			-0.097***	-0.100***
			(0.008)	(0.007)
[07] QDI			0.063***	0.061***
			(0.007)	(0.007)
[08] SEMI			0.080***	0.078***
			(0.012)	(0.011)
[09] PROF			0.237***	0.246***
			(0.014)	(0.011)
[10] EVB			-0.182***	-0.181***
			(0.008)	(0.008)
[11] QVB			-0.031***	-0.032***
			(0.008)	(0.008)
[12] MAN			0.015*	0.013*

Table 7 Robustness check: OLS estimation results based on stock-flow matching model and data set disaggregated by occupations and NUTS3 regions (*Continued*)

	Dependent variable: log *M*			
	OLS 1	OLS 2	OLS 3	OLS 4
			(0.008)	(0.007)
γ		1.597***	1.610***	1.555***
		(0.524)	(0.278)	(0.271)
a	-3.960***	-4.102***	-1.137**	-1.275***
	(0.595)	(0.570)	(0.436)	(0.394)
Control variables	Yes	Yes	Yes	Yes
Local area effects	Yes	Yes	Yes	Yes
Occupational yearly interaction effects	No	No	No	Yes
Quarter dummies	No	No	Yes	Yes
Observations	2,393,683	2,393,683	2,393,683	2,393,683
R-squared	0.725	0.726	0.741	0.742

Driscoll-Kraay standard errors in parentheses. Column OLS 4 includes yearly time and occupational category interaction effects (reference year is 2000, reference category is '[01] AGR Agrarian and not assignable occupations'), all dummy variables are effect coded, compare 'Effect coding' in the Appendix. Control variables are the share of female workers, the shares of workers at different skill levels ('vocational training' and 'academic degree,' reference group is 'without vocational training') in each NUTS3 region and occupation, and the average age by the population by NUTS3 regions. The estimated coefficients are provided on request.
[01] AGR agrarian and not assignable occupations, *[02] EMB* simple manual occupations, *[03] QMB* qualified manual occupations, *[04] TEC* technicians, *[05] ING* engineers, *[06] EDI* simple service occupations, *[07] QDI* qualified service occupations, *[08] SEMI* semi professions, *[09] PROF* professions, *[10] EVB* simple business and administrative occupations, *[11] QVB* qualified business and administrative occupations, *[12] MAN* manager
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Figs. 9 and 10 in the 'Further results' in the Appendix. Again, a 'crisis dip' arises after excluding the business cycle variable, $\mathrm{GDP}_{\mathrm{cyc,FS}(i),\mathrm{year}(t)}$, from the regression equation.

The results of the analysis for the occupational labour markets can be found in Table 7. The columns contain the results of specifications analogous to Table 4, augmented with the flow measures. Again, the results are quite similar to those based on the random matching approach.

Only the yearly deviations from average augmented productivity are mainly less volatile in the stock-flow matching approach than in the random matching model. Thus, the main conclusions of the previous section are unaffected. Finally, column OLS 4 reports the results of the full specification, including the year- and occupational-specific interaction effects. Again, I do not report the results for the specification, including year- and occupational-specific interaction effects (OLS 4), but I graphically show the point and interval estimations in Figs. 7 and 8.

Considering the results for the year- and occupational-specific interaction effects, there are only minor differences regarding the timing of the change and the further development of the matching efficiency.

Regarding the largest absolute changes of the yearly time fixed effects from year to year, Table 14 in 'Further results' in the Appendix shows hardly any differences compared with the results based on the random matching model (Table 13 in the Appendix) with the exception of the semi-professions and professions. For these occupational categories, the largest absolute changes in the yearly time fixed effects based on the stock-flow matching model was measured from 2004 to 2005 for the semi-professions and from 2008 to 2009 for the professions. However, regarding changes from 2004 to 2005, one should have in mind the data issues that were discussed in Section 3.

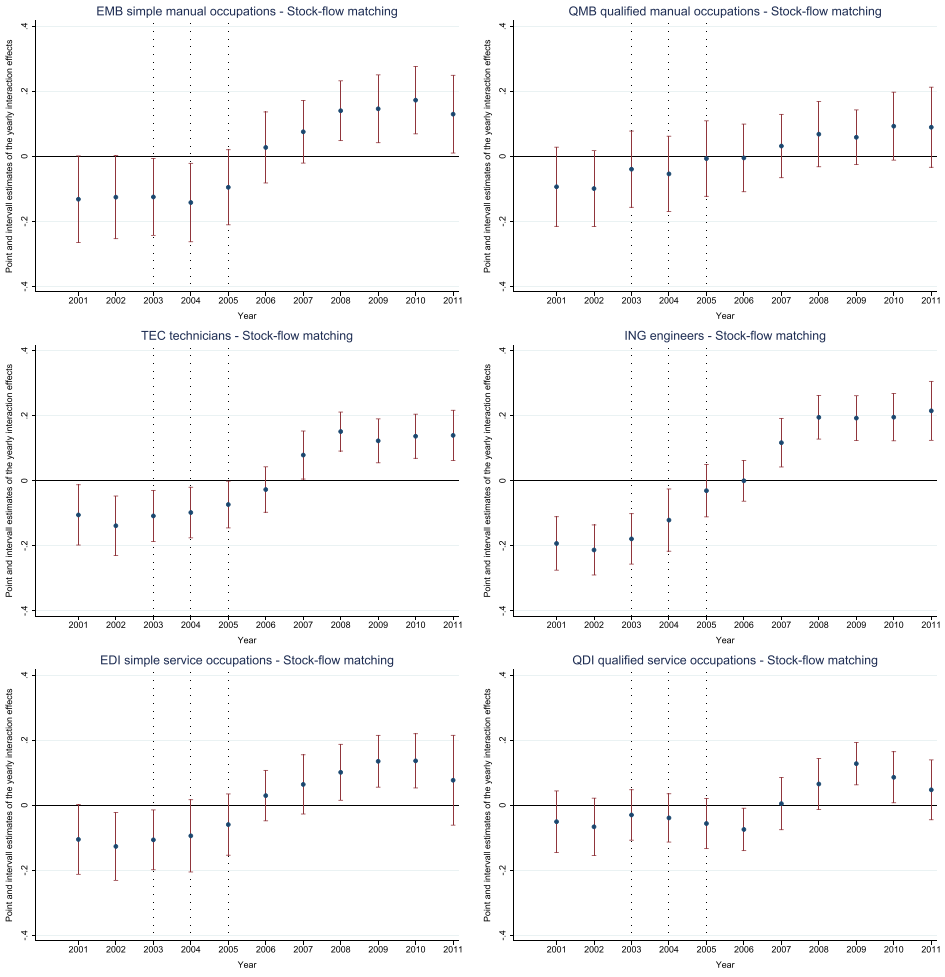

Fig. 7 Estimated sums of the yearly dummy and the yearly interaction effects and 95 % confidence band by occupational categories (part 1/2). Source: Statistics of the Federal Employment Agency, own computations. Notes: Graphs refer to column OLS 4 in Table 7, based on a data set disaggregated by occupations and NUTS3 regions. The *blue dots* and the *vertical red lines* mark the point and 95 % interval estimates

5.2 Aggregated data

Though it was necessary to account for cross-sectional dependence by computing Driscoll-Kraay standard errors, most of the estimates presented are highly significant. The reason for this result is the enormous variation in the data set the study is based on. From my knowledge, this study is the first to deliver such exact evidence. However, one shortcoming of such a detailed data is that the probability of measurement errors at the small local area level or occupational level increases. In aggregated data sets, these measurement errors could be 'compensated' for, and the prize are still higher standard errors. Because I am interested in the effects on partial labour markets, it is important to see whether the results would change after aggregating the data set. Therefore, I aggregated the data sets by NUTS3 regions over occupations and vice versa. As expected, the results show less precision, but the main conclusions remain stable. Compare Table 10 with Figs. 11 and 12 for the data set with NUTS3 regions as well as Table 11 with Figs. 13 and 14 for the data set with occupations, see 'Further results' in the Appendix.

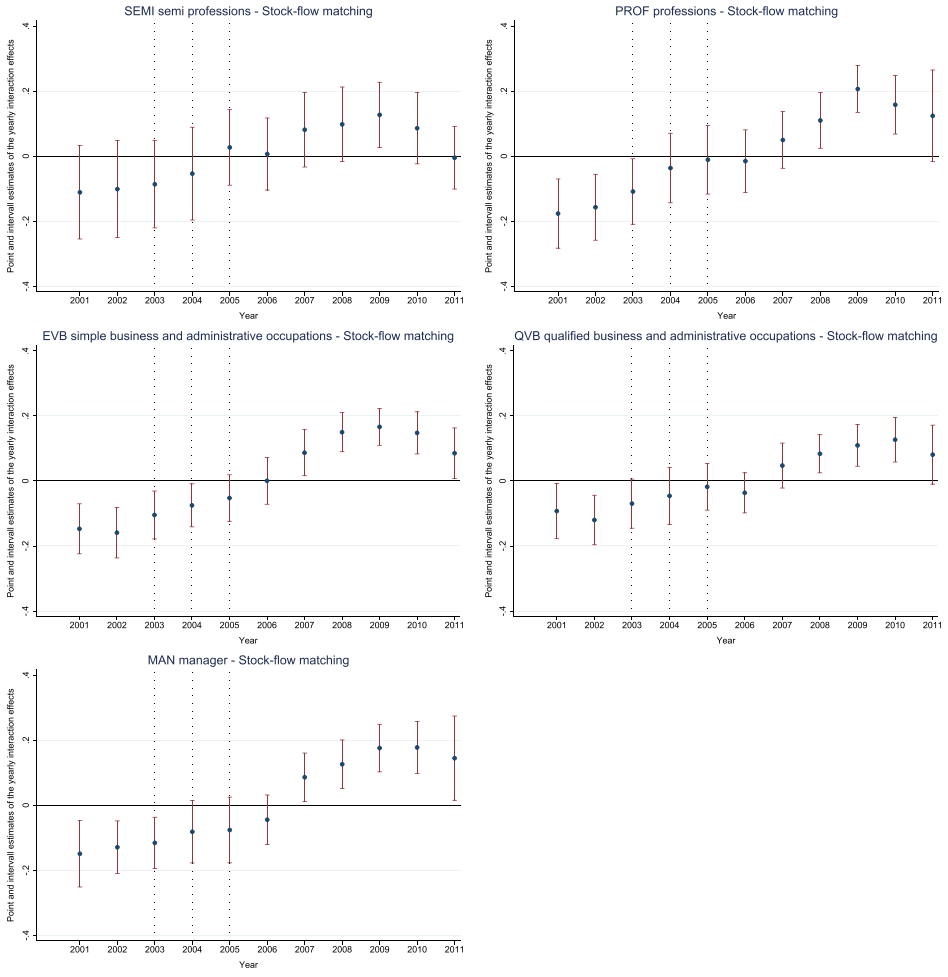

Fig. 8 Estimated sums of the yearly dummy and the yearly interaction effects and 95 % confidence band by occupational categories (part 2/2). Source: Statistics of the Federal Employment Agency, own computations. Notes: Graphs refer to column OLS 4 in Table 7, based on data set disaggregated by occupations and NUTS3 regions. The *blue dots* and the *vertical red lines* mark the point and 95 % interval estimates

6 Conclusions

In this paper, I present analyses of changes in the job matching productivity before, during, and after the German labour market reforms of 2003 to 2005, which are also known as the Hartz reforms, and an adjustment of unemployment benefits durations in 2006. Although one of the main objectives of the German labour market reforms was to improve the matching processes on the labour market, there are only a few studies that elucidate the direction and structure of the reform effects on job matching. Previous studies confirm positive effects, but there are different conclusions regarding the effects of the different reform stages. Furthermore, it was not known whether the reform effects covered the entire labour market or only parts of it. Another question is how the effects change during extreme economic situations like the financial crisis of 2008/2009.

The paper closes some of these gaps by estimating (unrestricted) macroeconomic matching function parameters on the basis of detailed, high-frequency and recent administrative panel data for the 2000–2011 period. To identify effects for occupational labour markets, I utilise an occupational category scheme that distinguishes between simple

manual occupations, qualified manual occupations, technicians, engineers, simple service occupations, qualified service occupations, semi-professions, professions, simple business and administrative occupations, qualified business and administrative occupations and managers.

The results complement previous findings and show differences in the changes of matching productivity in different occupational labour markets. In general, five important new conclusions can be derived: (1) matching productivity increased during all reform stages, including Hartz IV; (2) even after controlling for the business cycle, further increases of the matching productivity were deteriorated in 2009, the year of the financial crisis; (3) the positive changes become smaller in recent years; (4) positive changes in the matching efficiency during and after the reform years are observable in all occupational labour markets, as suggested, in particular, by the results of the analysis for these occupational labour markets; (5) the results for the point estimates suggest differences in the development of the matching productivity between the occupational labour markets in recent years, but the changes from year to year are not significant.

The results complement studies that find that the German reforms had positive effects on the labour market. It can be stated that a more efficient job matching contributes to a more successful realisation of companies' activity plans and, therefore, this higher efficiency should boost—rather than weaken—the standing of firms in their relevant markets.

Endnotes

[1] Klinger and Rothe (2012) generated a dummy variable that was valued at zero before 2005 and unity after 2005. Hillmann (2009) assumed an exponentially growing reform effect during the first 12 months after Hartz IV was implemented.

[2] German expression *"Fördern und Fordern"*.

[3] Thus, they estimated an averaged augmented productivity term before and after the reforms' implementation.

[4] *Klassifizierung der Berufe 1988.*

[5] Further information can also be found in 'Occupational labour markets' in the Appendix.

[6] Fahr and Sunde (2009) raised doubts that a macro evaluation of the last reform step in 2005 is hardly feasible within the framework that is used here and in other papers because it is not clear whether the further development in the matching efficiency after 2005 is an effect of the statistical break or due to changes in the matching efficiency. But the changes in the unemployment definitions went beyond a "statistical" break: before the last reform step in 2005, a certain part of persons capable to work were entitled to receive means tested social assistance ("Sozialhilfe für Erwerbsähige"). These persons were obliged to register as "job searchers" in their local agency but not as "unemployed" One could assume that the change of the 'employment' definition in 2005 changed also the support by the public placement officers for these persons who then received UB II. Though it is not possible to separately compare the efficiency of job search and matching with persons who received social assistance before and UB II after January 2005, it is of central interest of this and the other mentioned studies how the matching efficiency further developed after this institutional change.

[7] Excluding these controls hardly change the main results, the estimations without controls are provided on request. Further details about the four control variables can be found in 'Description and sources of the control variables' in the Appendix.

[8] Compare details about effect coding in 'Effect coding' in the Appendix.

[9] See 'Effect coding' in the Appendix.

[10] Details about the computation, the specifications and results are provided on request.

[11] I use the procedure conceived by Hoechle (2007) with a (default) lag length up to which the residuals may be autocorrelated of 4 ($m(T) = \text{floor}[\,4(T/100)^{2/9}] = 4, T = 138$).

[12] In addition, the identification might also be difficult due to possible anticipation effects, which would be the case when firms or the unemployed changed their search decisions after the reform plans were published but before these plans were realised.

[13] If I base this analysis on the assumption that the estimated average matching productivity (the constant in all models) for the 2000–2011 observation period is equivalent to long-term augmented productivity and should not change after varying the observation periods in the estimation, I might even conclude that the reform effects arise with a certain delay. However, this assumption can hardly be tested because it must be expected that a sample with fewer observation periods would reveal another value for the long-term augmented productivity and that massive short-term shocks on the labour market based on the Hartz reforms or the financial crisis would explain that more than 'invalid' data. This analysis implies that when there are substantial concerns about the value of the estimated augmented productivity, the observed positive or negative deviations from that productivity might be different based on the true value. However, the relative size of these time effects and a comparison of their year-to-year differences reveal that in 7 of 11 occupational categories, the highest positive change was from 2006 to 2007 (in addition to Figs. 4 and 5, which is shown in Table 13 in 'Year-to-year differences' in the Appendix). For the simple manual occupations (EMB) and the simple service occupations (EDI), this is 1 year earlier (2005/2006); for the professions (PROF), this is from 2003 to 2004; and for the qualified manual occupations (QMB), this is from 2002 to 2003.

Appendix

Occupational labour markets

Table 8 Assignment of Blossfelds occupational categories to the three-digit code of the German occupational classification scheme 1988 (*KldB 88*)

	KldB 88—occupational orders	
Occupational category	Code	Title
[01] AGR agrarian occupations	11	Farmers
	12	Winegrowers
	21	Livestock farmer
	22	Fish farmer
	41	Mixed crop and livestock farm labourers
	42	Livestock and dairy producers
	44	Pet groomers, animal care workers and related occupations
	51	Gardeners, horticultural and nursery growers
	53	Florists
	61	Forestry production managers, foresters and huntspersons
	62	Forestry labourers
[02 EMB simple manual occupations	71	Miners
	72	Mining shot firers and blasters
	81	Stone crushers
	82	Earth, gravel and sand quarry workers
	83	Gas and crude oil quarry workers
	91	Mineral and stone processing plant operators

Table 8 Assignment of Blossfelds occupational categories to the three-digit code of the German occupational classification scheme 1988 (*KldB 88*) (*Continued*)

	KldB 88—occupational orders	
Occupational category	Code	Title
	101	Stone splitters, cutters and carvers
	102	Precious-stone workers, jewel preparers
	111	Brickmakers and other stoneware makers
	112	Cement and concrete block makers
	121	Ceramics plant operators
	131	Frit makers, glass vitrifiers
	132	Hollow glassware makers
	133	Flat glass makers
	135	Glass cutters, grinders and refiners
	141	Chemical products, plant and machine operators
	143	Rubber products machine operators
	151	Plastic products machine operators
	161	Pulp and cellulose plant operators
	162	Packaging makers
	164	Other paper products machine operators
	176	Hecto- and mimeographers
	177	Printer's hands
	181	Wood-processing plant operators
	182	Woodworking machine setters and setter operators, and appropriate occupations
	183	Wood products, brush and cork maker
	184	Basketry weavers and wicker worker
	191	Ore and metal furnace operators, metal melters
	192	Rolling mill operators
	193	Metal drawers and extruders
	203	Casters of semi-finished products and other mould casters
	211	Sheet metal pressers, drawer and puncher
	212	Wire moulder, cable splicers
	213	Other metal moulders non cutting deformation
	222	Metal milling cutters
	223	Metal planers
	224	Metal borers
	225	Metal grinders
	226	Other metal-cutting occupations
	231	Metal polishers
	232	Engravers, chasers
	233	Metal finishers
	234	Galvanisers, metal colourers
	235	Enamelers, zinc platers and other metal surface finishers
	241	Welder, oxy-acetylene cutters
	242	Solderers
	243	Riveters
	244	Metal bonders and other metal connectors
	263	Pipe and tube fitters
	301	Precious fitters otherwise undisclosed
	313	Electric motor, transformer fitters
	321	Electrical appliance and equipment assemblers
	322	Metal, rubber, plastic, paperboard, textile and related products assemblers
	323	Metal plant operators no further specification

Table 8 Assignment of Blossfelds occupational categories to the three-digit code of the German occupational classification scheme 1988 (*KldB 88*) (*Continued*)

	KldB 88—occupational orders	
Occupational category	Code	Title
	332	Spoolers, twisters, rope makers
	341	Weaving and knitting machine preparers
	342	Weavers and weaving machine operators
	343	Tufted textile, fur and leather product makers
	344	Knitters and knitting machine operators
	345	Felt and hat body makers
	346	Textile braiders
	352	Sewers and sewing machine operators
	353	Lingerie tailors and sewers
	354	Embroiderers
	355	Hatters and cap makers
	356	Sewer and sewing machine operators otherwise undisclosed
	357	Other textile product makers
	361	Textile dyer and dyeing machine operators
	362	Textile bleaching, cleaning machine operators and other finishers
	371	Tanners, catgut string makers and other leather preparing machine operators
	373	Shoemaking machine operators
	375	Purse, hand bag and other fineleather products makers
	376	Leather garment makers and other leather products machine operators
	377	Leather glove makers
	402	Meat- and sausage-processing machine operators
	403	Fish-processing machine operators
	412	Ready-made meal-, fruit- and vegetable-processing machine operators
	424	Tobacco preparers, product makers
	431	Dairy product machine operators, butter, lard and margarine makers
	432	Grain- and spice-milling machine operators
	433	Sugar production machine operators, chocolate, sweets and ice cream makers
	442	Steel fixers, concrete workers
	452	Roofers
	453	Scaffolders
	461	Pavers
	462	Road building experts
	463	Track building experts
	465	Land improvement, maintenance and hydraulic structure building experts
	466	Well, duct and other civil engineering building experts
	471	Earth-moving labourers
	472	Building construction labourers and other construction and maintenance labourers otherwise undisclosed
	482	Insulators and proofers
	486	Composition floor and terrazzo layers
	504	Other wood product makers, boat, glider and wooden sports equipment building experts
	512	Goods painters and varnishers
	513	Wood surface finishers, veneers
	514	Glass, ceramics and related decorative painters, glass engravers and etchers
	521	Products testers, sorters otherwise undisclosed
	522	Product packagers, balers, wrappers, qualifiers and other loading agents
	531	Labourers not further specified

Table 8 Assignment of Blossfelds occupational categories to the three-digit code of the German occupational classification scheme 1988 (*KldB 88*) (*Continued*)

	KldB 88—occupational orders	
Occupational category	Code	Title
	543	Pump, compressor, assembly line, boring and other machines operators
	544	Crane and hoist plant operators
	545	Earth-moving and related plant operators
	546	Construction plant operators
	547	Machine maintenance operators, machinists' assistants
	548	Boiler persons, incinerators and related plant operators
	549	Machine tool setters and setter operators no further specified
[03] QMB qualified	134	Gaffer
manual occupations	142	Chemical laboratory workers
	144	Tyre vulcanisers
	163	Bookbinding workers
	171	Type setters, pre-press workers
	173	Book printers, letterpress
	174	Flat screen, gravure and intaglio printers
	175	Special, silk screen printers
	201	Moulders and core makers
	202	Casters
	221	Metal lathe operators
	251	Steel-, black-, hammersmiths and forging press workers
	252	Tank and container builders, coppersmiths and related occupations
	261	Tinsmiths
	262	Plumbers
	270	Locksmiths and fitters, not further specified
	271	Building fitters
	272	Sheet metal worker, plastics fitters
	273	Engine fitters
	274	Plant and maintenance fitters
	275	Steel construction fitters, steel ship builders
	281	Motor vehicle repairers
	282	Agricultural machinery repairers
	283	Aircraft mechanics
	284	Precision mechanics
	285	Other mechanics
	286	Watch-, clockmakers
	291	Toolmakers, instrument mechanics
	302	Precious metal smiths
	305	Musical instrument makers
	306	Doll, model makers, taxidermists
	311	Electrical fitters, mechanics
	312	Telecommunications mechanics, craftsmen
	314	Electrical appliance fitters
	315	Radio, sound equipment mechanics
	331	Spinner, fibre preparer
	351	Tailors and dressmakers
	372	Shoemakers
	374	Saddlers, truss makers and other coarse leather product makers
	378	Pelt dressers, furriers and other fur product makers
	391	Bakers and baked goods, cereal and chocolate product machine operators
	392	Pastry cooks and confectionery makers
	401	Butchers and stickers
	411	Cooks

Table 8 Assignment of Blossfelds occupational categories to the three-digit code of the German occupational classification scheme 1988 (*KldB 88*) (*Continued*)

	KldB 88—occupational orders	
Occupational category	Code	Title
	421	Wine coopers and other wine-processing operators
	422	Brewers, maltsters and other brewer machine operators
	423	Other beverage makers, coffee-processing machine operators, tasters and graders
	441	Bricklayers and masons
	451	Carpenters
	464	Shot firers and blasters except mining shot firers
	481	Stuccoers, plasterers
	483	Tile setters
	484	Stove setters and air heating fitters
	485	Glaziers
	491	Interior decorators, carpet and parquet layers
	492	Upholsterers, mattresses makers
	501	Cabinetmakers, carpenters and joiners
	502	Pattern and mould carpenters
	503	Cartwrights, wheelwrights, coopers and tubbers
	511	Construction painters, wallpaperers, varnishers
	541	Power production plant operators
	542	Winding, conveyor and ropeway machine operators
[04] TEC technicians	32	Agricultural engineers and advisors
	52	Garden and landscape architects and administrators
	303	Dental technicians
	304	Ophthalmic opticians
	601	Mechanical and automotive engineers
	602	Electrical and electronics engineers
	603	Architects, civil and structural engineers
	604	Cartographers and survey engineers
	605	Mining, metallurgy, foundry engineers
	606	Other production engineers
	607	Industrial and other operating engineers
	611	Chemists, chemical engineers
	612	Physicists, physics engineers, mathematicians
	621	Mechanical engineering technicians
	622	Electrical, electronics and telecommunications engineering technicians
	623	Civil engineering technicians
	624	Survey engineering technicians
	625	Mining, metallurgy, foundry engineering technicians
	626	Chemical and physical engineering technicians
	627	Other production technicians
	628	Industrial and other operating technicians
	629	Forepersons and other operations managers
	631	Agronomy, forestry and life science technicians
	632	Physical and mathematical science technicians
	633	Chemical science technicians
	634	Photo laboratory technicians
	635	Draftspersons
	721	Navigators, nautical ships' officers and pilots
	722	Technical ship's officers, engineers, technicians and machinists
	726	Aircraft pilots, flight engineers and other air traffic occupations
	733	Radio operators
	857	Medical technical, laboratory, radiological assistants
	883	Biologists, geographers, meteorologists and

Table 8 Assignment of Blossfelds occupational categories to the three-digit code of the German occupational classification scheme 1988 (*KldB 88*) (*Continued*)

Occupational category	KldB 88—occupational orders Code	Title
		other natural scientists, otherwise undisclosed
[06] EDI simple service occupations	685	Chemist's assistants in pharmacies
	686	Filling station attendants
	706	Cashiers, ticket agents, debt and vending machine money collectors and ticket inspectors
	713	Other brake, signal and switch operators, transport guides and conductors, fleet managers
	714	Car, taxi, bus, (heavy) truck and other motor vehicle drivers
	715	Cabby
	716	Construction and maintenance labourers: roads, dams, bridges and similar constructions
	723	Seagoing ships' deck crews
	724	Inland boatmen and related ships' decks crews
	725	Ferrymen, lockmasters, coastguards and other water traffic occupations
	741	Stocks administrators and clerks
	742	Lift, lifting-trucks and other materials handling equipment operators
	743	Longshoremen, furniture removers
	744	Stock, loading and other transport workers
	791	Factories security offices, store, hotel and other detectives
	792	Watchpersons, custodians, attendants and related workers
	793	Door-, gatekeepers and caretakers
	794	Menials, bellmen, ushers and groundkeepers
	805	Disinfectors, morticians, meat and and other health inspectors
	838	Clowns, magicians, acrobats, professional sportspersons, mountain guides and models
	911	Hoteliers, innkeepers, restaurateurs and management assistants in hotels and restaurants
	912	Waiters, waitresses, stewards, stewardesses and buspersons
	913	Porters, bartenders and other hotel and restaurant attendants
	923	Valets, chambermaids and other housekeeping attendants
	931	Launderers and ironers
	932	Textile cleaner, dyers, chemical purifiers
	933	Dishwashers, room and domestic cleaners
	934	Windows, frontages and buildings cleaners
	935	Sweepers, streets and sewerages cleaners, dustmen and other waste disposal workers
	936	Car washers, vehicle cleaners, car and vehicle carers
	937	Machinery, plant, tube and container cleaners
[07] QDI qualified service occupations	172	Stereotypers and electrotypers
	684	Chemists in drugstores
	704	Finance, stock, trade, ship, real estate, insurance brokers
	705	Landlords, hirers, agents, bookers, auctioneers
	711	Locomotive engine, tram and subway drivers
	712	Railway brake, signal and switch operators, shunters and railway guards and conductors
	801	Soldiers, border guards, police officers
	802	Firefighters
	803	Safety inspectors, trade controllers, gauging, and

Table 8 Assignment of Blossfelds occupational categories to the three-digit code of the German occupational classification scheme 1988 (*KldB 88*) (*Continued*)

	KldB 88—occupational orders	
Occupational category	Code	Title
		environmental protection officers
	804	Chimney sweepers
	812	Law officers
	814	Executory officers, prison guards
	831	Composers, music directors and musicians
	832	Film, stage and related directors, actors, singers and dancers
	833	Sculptors, painters, graphic and related artists
	834	Decorators, sign painters
	835	Set designer, light board, image and sound recording engineers, technicians and operators
	836	Interior architects, visual merchandiser
	837	Photographers, camera and retouching operators
	851	Non-medical practitioners, psychotherapists
	852	Masseurs, physiotherapists and health care professionals
	854	Paramedics and nursing auxiliary workers
	855	Dieticians, nutritionists and pharmacy technicians
	856	Doctor's receptionists and assistants
	892	Nuns, friars and other religious associate professionals
	893	Sextons, cantors and other religious assistants
	901	Hairdressers, barbers, wigmakers and related workers
	902	Beauticians, manicurists, pedicurists and related workers
	921	Housekeepers and related workers
	922	Energy and other consumer advisors
[08] SEMI semi professions	821	Authors, journalists, editors and announcers
	822	Interpreters, translators
	823	Librarians, archivists, documentalists, curators, library and filing clerks
	853	Nurses, midwifes, nursing and midwifery associate professionals
	861	Social work, welfare, health care professionals and workers; geriatric nurses
	862	Housemasters, social pedagogue, deacons
	863	Employment, vocational training, study, careers advisors
	864	Kindergarten teachers, child care workers and paediatric nurses
	873	Primary, secondary school, special education teachers and related teaching professionals
	874	Vocational, professional college teachers and related teaching professionals
	875	Art, music and voice teachers and related teaching professionals, otherwise undisclosed
	876	PE teachers, related teaching professionals, skiing and other sports instructors
	877	Driving, flying, hygienic and other instructors, otherwise undisclosed
[09] PROF professions	811	Judges and prosecutors
	813	Lawyers, notaries, legal representatives, advisors and other legal professionals
	841	Medical doctors
	842	Dentists
	843	Veterinaries
	844	Pharmacists
	871	University, college professors and related teaching professionals

Table 8 Assignment of Blossfelds occupational categories to the three-digit code of the German occupational classification scheme 1988 (*KldB 88*) (*Continued*)

	KldB 88—occupational orders	
Occupational category	Code	Title
	872	Grammar school teacher and related teaching professionals
	881	Economists, psychologists, sociologists, political scientists, statisticians
	882	Philologists, historians, philosophers and other humanities scientists, otherwise undisclosed
	891	Bishops, pastors, chaplains and other religious professionals
[10] EVB simple business and administrative occupations	682	Shop, stall and market salespersons and demonstrators
	687	Commercial sales representatives and sales agents
	732	Mail carriers, sorting clerks, porters and deliverers
	734	Telephone switchboard operators
	773	Cashiers and ticket clerks
	782	Secretaries, stenographers and typists
	783	Data entry operators
	784	Scribes and other office hands
[11] QVB qualified business and administrative occupations	31	Agricultural production manager
	681	Wholesaler, retail salespersons and buying agents
	683	Publishers, management assistants in publishing and booksellers
	691	Banking experts including tellers, finance clerks as well as finance dealers and brokers
	692	Building society experts including representatives as well as clerks
	693	Health insurance experts including representatives as well as clerks, not social security
	694	Life, property insurance experts including representative as well as clerks
	701	Logistics managers and transport clerks
	702	Travel agency clerks, attendants, stewards, consultants, organisers and guides
	703	Advertising and public relations experts
	771	Calculators, calculating and counting clerks
	772	Bookkeepers
	774	Computer scientists, equipment operators, computing and data processing professionals
	781	Office clerks, otherwise undisclosed
[12] MAN manager	751	Entrepreneurs, managing directors and division managers
	752	Management personnel and other business consultants
	753	Financial, tax accountants and accounting clerks
	762	Senior and administrative state officials
	763	Senior and administrative officials of humanitarian and other special-interest organisations
[00] not assignable	982	Interns, volunteer with occupation remaining to be specified
	983	Job-seekers with occupation remaining to be specified
	991	Labourers not further specified

Description and sources of the control variables

The data that is the base for the time series of the share of female employees and the shares of the employees with the skill levels 'without vocational training', 'vocational training', and 'academic degree' on all employees stem from the employers statistics from the Federal Employment Agency. This data is measured for the whole observation period at the level of occupational orders (three-digit level of the German occupational classification scheme 1988, KldB 88 and NUTS3 regions). The basis are employees subject to social contributions without employees in vocational training. For the data about skill levels, employees without an information about skill levels are not considered.

The data that is the base for the time series of the average age of the whole population stems from the Federal Statistical Office. It is measured for each of the observed NUTS 3 regions, and it comes in age groups. To compute an average for the population, the middle values of each age group are weighted by the number of persons in this group and the mean of these values are computed. However, since the oldest age group has no upper bound, I calculated the middle value for this group based on data for the whole economy that stems also from the Federal Statistical Office.

The time series of the German real gross domestic product (in the model denoted as GDP_{cyc}) stem from the Federal Statistical Office (National accounts). German real gross domestic product by Federal states calculated is measured on annual basis. The cyclical component is computed by using the Hodrick-Prescott filter with a smoothing parameter of 6.25. German real gross domestic product for the whole economy is measured on a quarterly basis. The cyclical component is computed by using the Hodrick-Prescott filter with a smoothing parameter of 1600.

More details about these data and the computation procedures are provided by the author on request.

Effect coding

The time dummy variables, the occupational labour market dummy variables and the interaction variables that are used in the regression equation to analyse occupational and time-specific changes in matching productivity are effect coded. The advantage of effect coding is that the coefficients can be directly interpreted as deviations from the general, the time or the occupational specific intercept in the model. This intercept can be interpreted as the average overall, time-specific or occupational matching productivity.

Formally, the time dummy variable d_y with $y = [2001, \ldots, 2011]$ with reference year 2000 is coded as follows:

$$d_y = \begin{cases} -1 & \text{year}(t) = 2000 \\ 0 & \text{year}(t) \neq y \\ 1 & \text{year}(t) = y \end{cases}$$

The occupational labour market dummy variables d_b with $b = [2, \ldots, 12]$ with reference category 'Agrarian and not assignable occupations' (occupational category = 1) are coded as follows:

$$d_b = \begin{cases} -1 & \text{occupational category}(j) = 1 \\ 0 & \text{occupational category}(j) \neq b \\ 1 & \text{occupational category}(j) = b \end{cases}$$

To measure the occupational category specific reform effects, I use effect-coded interaction dummy variables with the occupational reference category 'Agrarian and not assignable occupations' and the reference year 2000. This interaction effect variable $d_{b,y}$ with $y = [2001, \ldots, 2011]$ and $b = [2, \cdots, 12]$ is coded as follows:

$$d_{b,y} = \begin{cases} -1 & \text{year}(t) = 2000 \text{ and occupational category}(j) = 1 \\ 0 & \text{year}(t) \neq y \text{ and} \\ & \text{occupational category}(j) \neq b \\ 1 & \text{year}(t) = y \text{ and occupational category}(j) = b \end{cases}$$

Further results

Table 9 Fixed effects estimation results based on data set disaggregated by occupations and NUTS3 regions, all regressions without business cycle variable

	Dependent variable: log *M*					
	FE 1	FE 2	FE 3	FE 4	FE 5	FE 6
β_{Us}	0.580***	0.623***	0.624***	0.543***	0.563***	0.582***
	(0.013)	(0.009)	(0.010)	(0.016)	(0.013)	(0.014)
β_{Uf}				0.044***	0.071***	0.049***
				(0.014)	(0.009)	(0.011)
β_{Vs}	0.065***	0.040***	0.045***	0.036***	0.021***	0.023***
	(0.006)	(0.004)	(0.004)	(0.005)	(0.003)	(0.003)
β_{Vf}				0.044***	0.030***	0.034***
				(0.007)	(0.004)	(0.004)
Year dummies, effect coded (reference year: 2000):						
d_{2001}			-0.098***			-0.098***
			(0.031)			(0.030)
d_{2002}			-0.144***			-0.136***
			(0.026)			(0.026)
d_{2003}			-0.134***			-0.127***
			(0.017)			(0.017)
d_{2004}			-0.122***			-0.119***
			(0.019)			(0.019)
d_{2005}			-0.103***			-0.096***
			(0.022)			(0.022)
d_{2006}			-0.023*			-0.016
			(0.014)			(0.015)
d_{2007}			0.098***			0.101***
			(0.019)			(0.019)
d_{2008}			0.172***			0.167***
			(0.013)			(0.013)
d_{2009}			0.087***			0.080***
			(0.015)			(0.015)

Table 9 Fixed effects estimation results based on data set disaggregated by occupations and NUTS3 regions, all regressions without business cycle variable (*Continued*)

d_{2010}			0.162***			0.151***
			(0.021)			(0.020)
d_{2011}			0.159***			0.150***
			(0.020)			(0.020)
a	-4.533***	-1.013**	-0.963**	-4.449***	-0.948**	-0.954**
	(0.633)	(0.403)	(0.417)	(0.609)	(0.405)	(0.419)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Monthly time dummies	No	Yes	No	No	Yes	No
Quarter dummies	No	Yes	No	No	Yes	No
Observations	2,393,683	2,393,683	2,393,683	2,393,683	2,393,683	2,393,683
Number of groups	55,316	55,316	55,316	55,316	55,316	55,316
Within R-squared	0.236	0.304	0.274	0.241	0.309	0.278

Driscoll-Kraay standard errors in parentheses. Columns FE 2 and FE 5 include monthly time fixed effects with effect coding (reference period is January 2000), compare with Fig. 9 in the Appendix. Control variables are the share of female workers, the shares of workers at different skill levels ('vocational training' and 'academic degree', reference group is 'without vocational training') in each NUTS3 region and occupation, and the average age by the population by NUTS3 regions. The estimated coefficients are provided on request

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

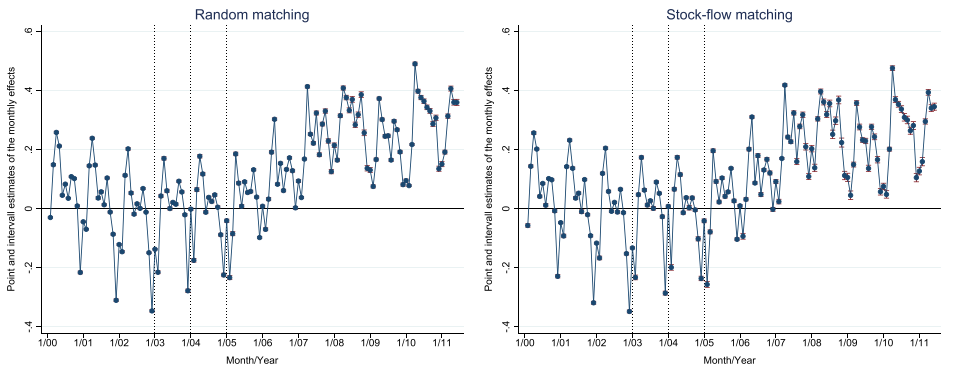

Fig. 9 Monthly time fixed effects and 95 % confidence band. Source: Statistics of the Federal Employment Agency, own computations. Notes: Specifications from Table 9 in the Appendix, *left side* FE 2, *right side* FE 5, based on data set disaggregated by occupations and NUTS3 regions, all regressions without business cycle variable. The *blue dots* and the *vertical red lines* mark the point and 95 % interval estimates; the interval is very small in some cases. The dots are linked with a line to illustrate the temporal development. Monthly time fixed effects with effect coding (reference period is January 2000)

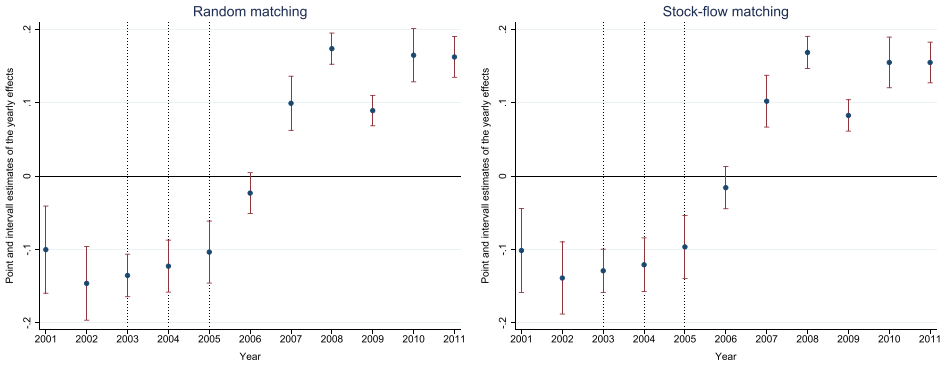

Fig. 10 Yearly time fixed effects and 95 % confidence band. Source: Statistics of the Federal Employment Agency, own computations. Notes: Specifications from Table 9 in the Appendix, *left side* FE 3, *right side* FE 6, based on a data set disaggregated by occupations and NUTS3 regions, all regressions without business cycle variable. The *blue dots* and the *vertical red lines* mark the point and 95 % interval estimates; the interval is very small in some cases. Yearly time fixed effects with effect coding (reference period is 2000)

Table 10 Fixed effects estimation results based on data set disaggregated by NUTS3 regions

	Dependent variable: log *M*							
	FE 1	FE 2	FE 3	FE 4	FE 5	FE 6	FE 7	FE 8
β_{Us}	0.691***	0.702***	0.601***	0.676***	0.832***	0.836***	0.516***	0.736***
	(0.050)	(0.050)	(0.034)	(0.042)	(0.066)	(0.065)	(0.042)	(0.057)
β_{Uf}					-0.238***	-0.230***	0.150***	-0.108**
					(0.051)	(0.052)	(0.038)	(0.047)
β_{Vs}	0.173***	0.158***	0.065***	0.113***	0.029	0.018	0.027***	0.031**
	(0.031)	(0.031)	(0.013)	(0.020)	(0.026)	(0.026)	(0.010)	(0.014)
β_{Vf}					0.201***	0.200***	0.076***	0.144***
					(0.035)	(0.035)	(0.015)	(0.025)
Year dummies, effect coded (reference year: 2000):								
d_{2001}				-0.138***				-0.187***
				(0.048)				(0.045)
d_{2002}				-0.164***				-0.169***
				(0.039)				(0.037)
d_{2003}				-0.097***				-0.096***
				(0.029)				(0.029)
d_{2004}				-0.062**				-0.055*
				(0.031)				(0.031)
d_{2005}				-0.024				-0.022
				(0.036)				(0.033)
d_{2006}				-0.002				-0.005
				(0.020)				(0.020)
d_{2007}				0.066**				0.072**
				(0.031)				(0.030)
d_{2008}				0.131***				0.151***
				(0.026)				(0.027)
d_{2009}				0.119***				0.166***
				(0.032)				(0.031)
d_{2010}				0.164***				0.189***
				(0.035)				(0.034)

Table 10 Fixed effects estimation results based on data set disaggregated by NUTS3 regions (*Continued*)

d_{2011}				0.086**				0.102**
				(0.041)				(0.040)
γ		1.274**	1.024**	1.041**		0.986*	1.135**	1.223**
		(0.591)	(0.494)	(0.496)		(0.562)	(0.464)	(0.478)
a	-4.246***	-4.796***	0.164	-0.871	-5.534***	-5.960***	-0.440	-0.750
	(1.234)	(1.246)	(0.758)	(0.803)	(1.098)	(1.080)	(0.728)	(0.794)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Monthly time dummies	No	No	Yes	No	No	No	Yes	No
Quarter dummies	No	No	No	Yes	No	No	No	Yes
Observations	55,371	55,371	55,371	55,371	55,371	55,371	55,371	55,371
Number of groups	402	402	402	402	402	402	402	402
Within R-squared	0.244	0.250	0.668	0.428	0.309	0.313	0.677	0.448

Driscoll-Kraay standard errors in parentheses. Columns FE 3 and FE 7 include monthly time fixed effects with effect coding (reference period is January 2000), compare with Fig. 11 in the Appendix. Control variables are the share of female workers, the shares of workers at different skill levels ('vocational training' and 'academic degree', reference group is 'without vocational training') in each NUTS3 region and occupation, and the average age by the population by NUTS3 regions. The estimated coefficients are provided on request

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

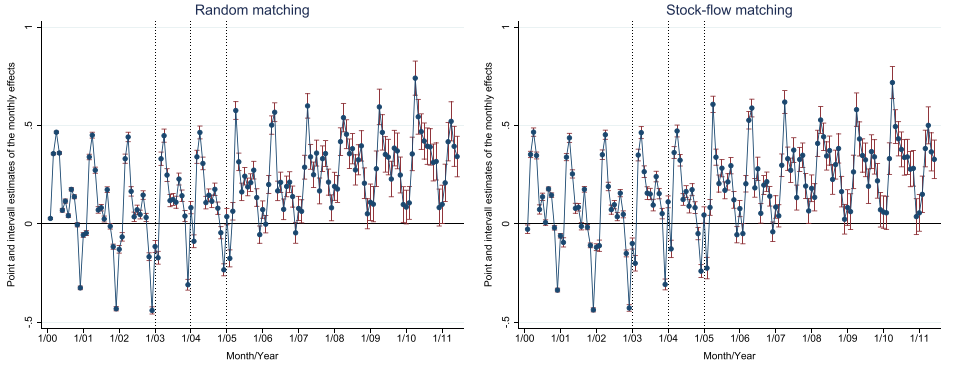

Fig. 11 Monthly time fixed effects and 95 % confidence band. Source: Statistics of the Federal Employment Agency, own computations. Notes: Specifications from Table 10 in the Appendix, *left side* FE 3, *right side* FE 7, based on data set disaggregated by NUTS3 regions. The *blue dots* and the *vertical red lines* mark the point and 95 % interval estimates; the interval is very small in the some cases. The *dots* are linked with a *line* to illustrate temporal development. Monthly time fixed effects with effect coding (reference period is January 2000)

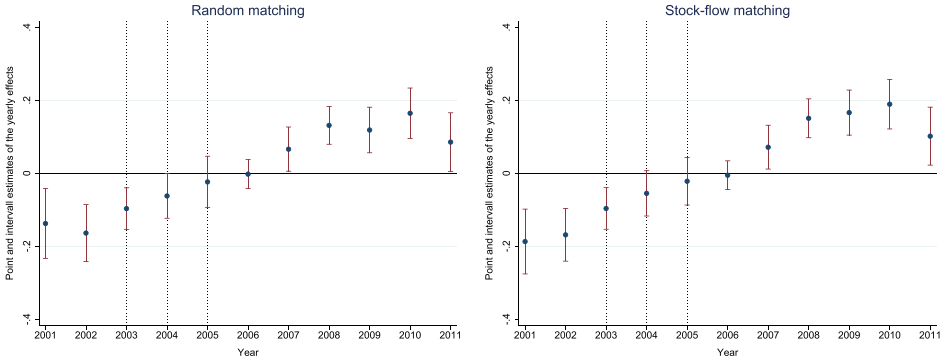

Fig. 12 Yearly time fixed effects and and 95 % confidence band. Source: Statistics of the Federal Employment Agency, own computations. Notes: Specifications from Table 10 in the Appendix, *left side* FE 4, *right side* FE 8, based on data set disaggregated by NUTS3 regions. The *blue dots* and the *vertical red lines* mark the point and 95 % interval estimates. Yearly time fixed effects with effect coding (reference period is 2000)

Table 11 Fixed effects estimation results based on data set disaggregated by occupations

	Dependent variable: log *M*							
	FE 1	FE 2	FE 3	FE 4	FE 5	FE 6	FE 7	FE 8
β_{Us}	0.867***	0.896***	0.929***	0.930***	0.925***	0.936***	0.838***	0.948***
	(0.022)	(0.021)	(0.013)	(0.014)	(0.045)	(0.044)	(0.042)	(0.041)
β_{Uf}					-0.083*	-0.065	0.086**	-0.035
					(0.047)	(0.045)	(0.041)	(0.041)
β_{Vs}	0.143***	0.124***	0.087***	0.098***	0.056***	0.041***	0.030***	0.033***
	(0.015)	(0.014)	(0.008)	(0.008)	(0.017)	(0.014)	(0.007)	(0.009)
β_{Vf}					0.112***	0.108***	0.072***	0.084***
					(0.018)	(0.019)	(0.008)	(0.011)
Year dummies, effect coded (reference year: 2000):								
d_{2001}				-0.343***				-0.365***
				(0.045)				(0.044)
d_{2002}				-0.349***				-0.348***
				(0.036)				(0.035)
d_{2003}				-0.260***				-0.266***
				(0.027)				(0.029)
d_{2004}				-0.173***				-0.182***
				(0.025)				(0.026)
d_{2005}				-0.086**				-0.097**
				(0.038)				(0.039)
d_{2006}				-0.032*				-0.032
				(0.019)				(0.020)
d_{2007}				0.144***				0.158***
				(0.042)				(0.041)
d_{2008}				0.287***				0.306***
				(0.049)				(0.051)
d_{2009}				0.346***				0.361***
				(0.061)				(0.060)

Table 11 Fixed effects estimation results based on data set disaggregated by occupations (*Continued*)

d_{2010}				0.405***				0.417***
				(0.026)				(0.028)
d_{2011}				0.349***				0.368***
				(0.035)				(0.037)
γ		2.123***		1.804		1.956***		1.617
		(0.640)		(1.376)		(0.639)		(1.354)
a	-11.549***	-12.287***			-12.761***	-13.268***		
	(1.183)	(1.263)			(1.174)	(1.241)		
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Monthly time dummies	No	No	Yes	No	No	No	Yes	No
Quarter dummies	No	No	No	Yes	No	No	No	Yes
Observations	42,053	42,053	42,053	42,053	42,053	42,053	42,053	42,053
Number of groups	327	327	327	327	327	327	327	327
Within R-squared	0.552	0.561	0.676	0.611	0.564	0.572	0.681	0.617

Driscoll-Kraay standard errors in parentheses. Columns FE 3 and FE 7 include monthly time fixed effects with effect coding (reference period is January 2000), compare with Fig. 13 in the Appendix. Due to collinearity, specifications FE 3 and FE 7 without $GDP_{cyc,quarter(t)}$ and the constant term *a*; FE 4 and FE 8 without the constant term. Control variables are the share of female workers, the shares of workers at different skill levels ('vocational training' and 'academic degree', reference group is 'without vocational training') in each NUTS3 region and occupation, and the average age by the population by NUTS3 regions. The estimated coefficients are provided on request

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

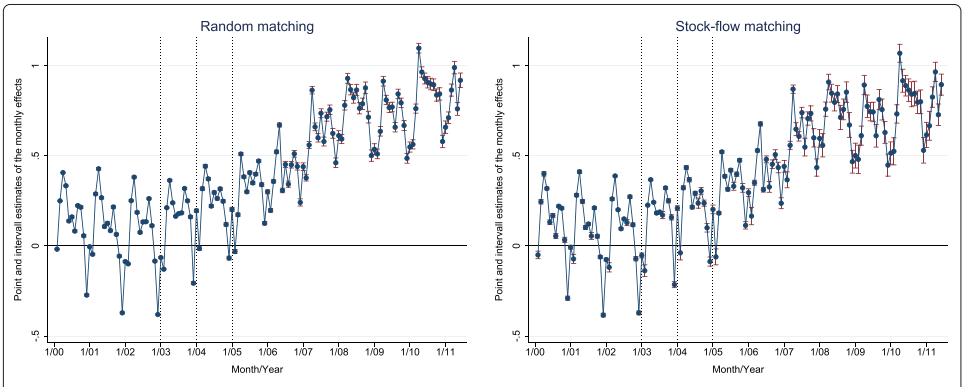

Fig. 13 Monthly time fixed effects and 95 % confidence band. Source: Statistics of the Federal Employment Agency, own computations. Notes: Specifications from Table 11 in the Appendix, *left side* FE 3, *right side* FE 7, based on data set disaggregated by occupations. The *blue dots* and the *vertical red lines* mark the point and 95 % interval estimates; the interval is very small in some cases . The *dots* are linked with a *line* to illustrate the temporal development. Monthly time fixed effects with effect coding (reference period is January 2000)

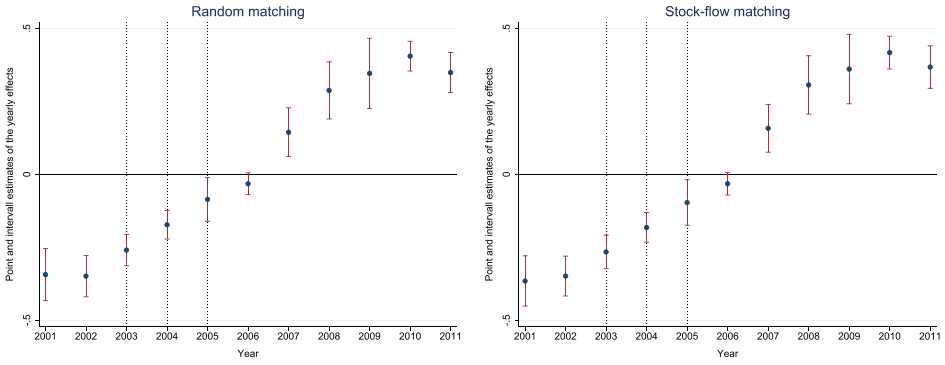

Fig. 14 Yearly time fixed effects and 95 % confidence band. Source: Statistics of the Federal Employment Agency, own computations. Notes: Specifications from Table 11 in the Appendix, *left side*: FE 4, *right side* FE 8, based on data set disaggregated by occupations.The *blue dots* and the *vertical red lines* mark the point and 95 % interval estimates; the interval is very small in some cases. The *dots* are linked with a *line* to illustrate the temporal development. Monthly time fixed effects with effect coding (reference period is January 2000)

Predicted matching efficiencies

In the following Table 12 in the Appendix, I report predicted yearly values of the logarithm of (averages of) the augmented matching productivity A, referring to Eq. (1), and specifications without (Eq. 3) and with business cycle variable (Eq. 4, additional term in square brackets):

$$\widehat{\log A_{\text{year}}} \equiv \overline{\widehat{\log A_{ijt}}} = \bar{\hat{a}} + \overline{\hat{\mu}_{ij}} + \overline{\hat{\theta}\mathbf{X_t}}[+\gamma\overline{\text{GDP}_{\text{cyc,FS}(i),\text{year}(t)}}] \tag{9}$$

Other frequencies, e.g. monthly values, or other aggregation levels, like occupational labour markets, are also computable and will be provided by the author on request.

Table 12 Predicted values for the augmented matching efficiency A (and $\log A$) based on the estimates from specifications with and without the business cycle variable (BC)

Years	Specification			
	With BC variable FE 3 in Table 3		Without BC variable FE 2 in Table 9 in the Appendix	
	$\widehat{A}$	$\log\widehat{A}$	$\widehat{A}$	$\log\widehat{A}$
2000	0.409718215	-0.892285645	0.411119014	-0.888872564
2001	0.391941965	-0.936641514	0.393890768	-0.931681633
2002	0.374092937	-0.983251035	0.376081556	-0.977949262
2003	0.378048003	-0.972734094	0.380084157	-0.967362583
2004	0.382968634	-0.95980221	0.38472423	-0.955228508
2005	0.390673935	-0.93988198	0.39214623	-0.93612045
2006	0.4240987	-0.85778904	0.425949901	-0.853433549
2007	0.479338318	-0.735348642	0.481756747	-0.730315983
2008	0.515441298	-0.662731826	0.518508852	-0.656798184
2009	0.473781496	-0.747009039	0.47628665	-0.741735399
2010	0.512100458	-0.669234455	0.514599204	-0.664366901
2011	0.517209411	-0.65930742	0.519226968	-0.655414164

Source: Statistics of the Federal Employment Agency, own computations

Year-to-year differences

Table 13 Absolute year-to-year differences between the yearly time fixed effects sums from Figs. 4 and 5, based on the random matching model

Occupational category	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011
[2]EMB	-0.005	0.006	0.004	0.023	**0.140**	0.075	0.103	0.017	0.047	-0.049
[3] QMB	-0.029	**0.067**	0.009	0.026	0.009	0.056	0.061	-0.013	0.049	-0.011
[4] TEC	-0.038	0.040	0.047	0.015	0.040	**0.124**	0.093	-0.029	0.025	-0.007
[5] ING	-0.029	0.042	0.079	0.075	0.019	**0.128**	0.103	0.000	0.003	0.016
[6] EDI	-0.043	0.031	0.032	0.008	**0.099**	0.056	0.073	0.037	0.025	-0.059
[7] QDI	-0.031	0.054	0.017	-0.038	-0.024	**0.096**	0.087	0.058	-0.034	-0.044
[8] SEMI	-0.011	0.031	0.063	0.073	-0.024	**0.087**	0.043	0.018	-0.038	-0.101
[9] PROF	0.004	0.064	**0.098**	0.016	-0.022	0.075	0.078	0.091	-0.054	-0.030
[10] EVB	-0.015	0.071	0.053	-0.007	0.051	**0.099**	0.096	0.018	-0.010	-0.066
[11] QVB	-0.046	0.052	0.051	0.012	-0.013	**0.101**	0.071	0.022	0.020	-0.053
[12] MAN	0.010	0.019	0.064	-0.001	0.039	**0.149**	0.071	0.048	-0.005	-0.034

Source: Statistics of the Federal Employment Agency, own computations. Bold printed values denote the maximal positive absolute changes of the time fixed effects.
[01] AGR agrarian and not assignable occupations, *[02] EMB* simple manual occupations, *[03] QMB* qualified manual occupations, *[04] TEC* technicians, *[05] ING* engineers, *[06] EDI* simple service occupations, *[07] QDI* qualified service occupations, *[08] SEMI* semi-professions, *[09] PROF* professions, *[10] EVB* simple business and administrative occupations, *[11] QVB* qualified business and administrative occupations, *[12] MAN* manager

Table 14 Absolute year-to-year differences between the yearly time fixed effects sums from Figs. 7 and 8, based on the stock-flow matching model

Occupational category	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011
[2] EMB	0.022	0.009	-0.015	0.048	**0.125**	0.044	0.059	0.010	0.030	-0.041
[3] QMB	-0.002	**0.064**	-0.014	0.048	0.000	0.028	0.029	-0.013	0.040	-0.005
[4] TEC	-0.031	0.038	0.023	0.026	0.040	**0.092**	0.057	-0.035	0.035	0.000
[5] ING	-0.021	0.039	0.062	0.085	0.022	**0.107**	0.064	-0.012	0.018	0.014
[6] EDI	-0.018	0.025	0.017	0.040	**0.098**	0.038	0.036	0.027	0.012	-0.053
[7] QDI	-0.018	0.041	-0.003	-0.013	-0.015	**0.078**	0.049	0.047	-0.037	-0.037
[8] SEMI	0.004	0.015	0.039	**0.084**	-0.016	0.076	0.009	0.012	-0.038	-0.090
[9] PROF	0.017	0.051	0.077	0.025	-0.006	0.058	0.047	**0.079**	-0.043	-0.034
[10] EVB	-0.010	0.067	0.038	0.021	0.051	**0.080**	0.055	0.009	-0.011	-0.063
[11] QVB	-0.025	0.055	0.028	0.027	-0.019	**0.078**	0.027	0.016	0.026	-0.047
[12] MAN	0.018	0.025	0.045	0.005	0.034	**0.125**	0.034	0.041	0.013	-0.031

Source:Statistics of the Federal Employment Agency, own computations. Bold printed values denote the maximal positive absolute changes of the time fixed effects.
[01] AGR agrarian and not assignable occupations, *[02] EMB* simple manual occupations, *[03] QMB* qualified manual occupations, *[04] TEC* technicians, *[05] ING* engineers, *[06] EDI* simple service occupations, *[07] QDI* qualified service occupations, *[08] SEMI* semi-professions, *[09] PROF* professions, *[10] EVB* simple business and administrative occupations, *[11] QVB* qualified business and administrative occupations, *[12] MAN* manager

Competing interests
The IZA Journal of European Labor Studies is committed to the IZA Guiding Principles of Research Integrity. The author declares that he has observed these principles.

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