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A Cointegration Model for Search Equilibrium Wage Formation

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Tinbergen Institute Discussion Paper

A Cointegration Model for Search Equilibrium Wage Formation

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A Cointegration Model for Search Equilibrium

Wage Formation

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October 2003

ABSTRACT

In flow models of the labor market, wages are determined by negotiations between workers and employers on the surplus value of a realized match. From this perspective our study presents an econometric analysis of the influence of labor market flows on wage formation as alternative to the traditional specification of wage equations where unemployment represents the Phillips-curve or wage curve-effects. We estimate a dynamic wage equation for the Netherlands using a cointegration approach. We find that labor flows, and notably flows from outside the labor market, are important determinants for both short run and long run wage setting.

JEL codes: J31, C51

Key words: wage curve, labor market flows, cointegration model

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Wage Formation

ABSTRACT

In flow models of the labor market, wages are determined by negotiations between workers and employers on the surplus value of a realized match. From this perspective our study presents an econometric analysis of the influence of labor market flows on wage formation as alternative to the traditional specification of wage equations where unemployment represents the Phillips-curve or wage curve-effects. We estimate a dynamic wage equation for the Netherlands using a cointegration approach. We find that labor flows, and notably flows from outside the labor market, are important determinants for both short run and long run wage setting.

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1. Introduction

Modern empirical studies of the labor market pay ample attention to labor market dynamics. Besides job destruction, job creation and job-to-job mobility, wage formation forms a corner stone of these studies (Blanchard and Diamond (1992), and Mortensen and Pissarides (1994)). The theoretical basis is the equilibrium search model, in which wage formation is described as a Nash bargaining problem of sharing the local monopoly rent of a successful match between an employer and an employee (see, e.g., Pissarides (1996)). In this paper we apply this theory to derive an empirical wage equation. Specifically, we specify a wage equation for the Netherlands that is derived from a Nash bargaining process in a flow model with three labor market states: employed, unemployed, and outside the labor market. The outcome of the bargaining process yields a specification of the wage equation with various flows between these labor market states as determinants.

Our specification of the wage equation extends the traditional specifications of the wage equation, which includes some measure of unemployment as a determinant of wages. Phillips' (1958) empirical relationship between wages and unemployment nowadays has a number of alternative theoretical foundations. Phelps (1968) has shown how the Phillips curve effect can be derived from the behavior of the firm. In a newer tradition, trade union behavior has been shown to imply the so-called wage-curve effect (Oswald (1982), Blanchflower and Oswald (1990), and Graafland (1992)). However, neither of these theoretical derivations of the wage equation prescribes that the unemployment rate or some transformation thereof should act as a measure for labor market tightness.

Instead, the theory allows for a much wider set of indicators. In this respect Blanchard and Katz (1997) point at the importance of labor market flows for wage setting, although their empirical estimates consider only the relationship between unemployment and wages. Broersma and Den Butter (2001, 2002) estimate specifications of wage equations where various labor flow variables that represent labor market tightness are included on an ad hoc basis. This paper builds on these previous studies. From a formal theoretical model we derive a specification of a flow-based wage equation, which is estimated using the cointegration approach. In our estimates we use aggregate time series data on these labor flows for the Netherlands, constructed according to a recently developed national accounting method (Broersma, Den Butter and Kock (2000), and Kock (2002)).

In the next section the theoretical specification of the flow-based wage equation is presented. There it is also shown how our specification relates to traditional empirical studies of the labor market. Section 3 describes the flow data that we use and it presents our cointegration estimates of the wage equation, and Section 4 concludes.

2. Wages as a shared surplus of matches at the labor market

Equilibrium search theory, which is the theoretical background of empirical flow models of the labor market, provides an adequate framework for the inclusion of labor market flows as determinants in the wage equation. Millard's (1997) unemployment equilibrium model, for example, views wages as the result of bilateral bargaining

between the firm and the worker. Following Millard and Mortensen (1997) he assumes that bargaining is carried out in such a way to ensure efficient job destruction, i.e. jobs are only destroyed when it is in the interest of both the worker and the employer. Alternatively, in an empirical model of labor market dynamics Gautier (1997) follows the theoretical argumentation of Diamond (1982), Mortensen (1982) and Pissarides (2000) and derives a wage equation from the assumption that the surplus of a match is shared between the worker and the employer according to a Nash bargaining game. The solution of this game yields a wage equation in which outflow rates from employment and unemployment and outflow rates of vacancies determine wages.

We follow the Diamond-Mortensen-Pissarides approach and derive a basic equation for wage formation where wages are determined as a shared surplus of matches of employers seeking for workers and workers searching for jobs. In equilibrium, the inflow into employment and unemployment equals the outflow. We start by writing down asset values for each of the worker and job states. For simplicity it is assumed that job destruction is an exogenous process. To avoid clutter we omit the time index t in this presentation, but note that the denominator of the flow rates should be lagged one period.

A Basic Search Equilibrium Wage Equation

The asset value of being employed is equal to the wage minus the probability to become unemployed (the lay-off rate) times the associated wealth loss of becoming unemployed, plus the expected change in the job value or:

$$iW_E = w - \frac{F_{EU}}{E} [W_E - W_U] + \dot{W}_E, \quad [1]$$

where i represents the discount rate, w is the real wage rate, W_E is the asset value of being employed, W_U is the asset value of being unemployed, F_{EU} is the flow of workers from employment to unemployment and E is the employment stock. The dot indicates the expected change in the asset value, which is zero in equilibrium. Similarly, the asset value of being unemployed is given by

$$iW_U = b + \frac{F_{UE}}{U} [W_E - W_U] + \dot{W}_U, \quad [2]$$

where b is a flat rate unemployment benefit, and U is the unemployment stock. We ignore other (expected) real returns that the worker might enjoy while unemployed (cf. Pissarides (2000); p. 13). Along the same lines we can define the asset value of a filled job, W_F . It is equal to the real value added (y) per worker minus wage costs (w) minus the lay-off rate (F_{EU}/E) times the associated wealth change when the job is abandoned,

$$iW_F = y - w - \frac{F_{EU}}{E} [W_F - W_V] + \dot{W}_F. \quad [3]$$

Finally, the asset value of an unfilled vacancy (W_V) is equal to the probability that it will be filled times the associated change in wealth minus the costs of forgone output and the costs of posting the vacancy, such as advertisement costs,

$$iW_V = \frac{F_{UE}^v}{V} [W_F - W_V] - yc + \dot{W}_V. \quad [4]$$

F_{UE}^v is the rate at which vacancies are filled up and it is defined by an aggregate matching function. We assume that the hiring costs (c) are proportional to the real value added per worker, which equals the value of the vacancy if a worker were to fill it.

The surplus of a match is shared between the worker and the employer according to a Nash bargaining game. Like in the traditional wage curve models it is assumed that a generalized Nash bargaining solution formalizes the outcome of the bargaining process between a representative employee (or union) and a representative employer (or employers' organization),

$$\max_{w_i} \Omega(w_i) = [W_E - W_U]^\beta [W_F - W_V]^{1-\beta}. \quad [5]$$

This is similar to the bargaining solution of a traditional wage curve model, where the worker's and employer's threat points represent their utility during a breakdown in the bargaining process. In the bargaining solution [5] of the equilibrium search model the threat points W_U for workers and W_V for employers represent the present value of (expected) income streams of an unemployed worker and the present value of the expected profit from a vacant job, respectively. β is a parameter representing the relative

bargaining strength of the worker, or the union¹. It can be shown from the first- and second-order conditions of [5] that any exogenous variable that increases the threat point present value of the worker's income stream or decreases the threat point present value of the employer's income stream, raises the wage outcome of the bargaining process. Hence, a higher replacement rate increases the wage bargaining outcome.

The first order maximization conditions for both the worker and employer surplus imply $(1 - \beta)[W_E - W_U] = [W_F - W_V]$. We can now derive the wage equation by imposing the condition that in equilibrium all profit opportunities from new jobs are exhausted and hence the value of a newly opened vacancy is zero, $W_V = 0$. Note that in equilibrium the expected change in the value of a particular state (unemployed or employed) or job (filled or vacant) is also zero. Following Pissarides we can derive an expression of the wage by imposing the equilibrium condition and substituting W_E and W_V from [1] and [4] into [5], to arrive at $w = iW_U + \beta(y - iW_U)$. We use the Nash bargaining solution and the equilibrium condition for vacant jobs, $W_V = 0$, to arrive at

$$iW_U = b + \frac{F_{UE}}{U} \left(\frac{\beta}{1 - \beta} \left(\frac{yc}{F_{UE}^v/V} \right) \right),$$

which we substitute into the previous expression for w to find a convenient expression for the equilibrium wage rate²,

¹ It is usually assumed that β equals 0.5 but there may be circumstances that justify a different β , for example when employers and unions have different rates of impatience (Pissarides (2000)).

² This equilibrium condition implies that $W_F = yc / (F_{UE}^v/V)$.

$$w = (1 - \beta)b + \beta y \left(1 + c \frac{F_{UE}}{U} \frac{V}{F_{UE}^v} \right). \quad [6]$$

If we assume that all workers find a job by filling a vacancy, so $F_{UE} = F_{UE}^v$, then we can rewrite [6] as $w = (1 - \beta)b + \beta y(1 + c\theta)$. This is the basic aggregate equilibrium wage equation in Pissarides' equilibrium search model with θ representing a measure of labor market tightness $U/V/U$. Note that the interest rate i drops out of the wage equation.

Adding taxes, wage related benefits, and non-participants

The wage equation [6] can be refined by including proportional income taxes t for workers and replacing the flat rate unemployment benefits b by wage related benefits (represented by the replacement rate rr times the wage rate). Similar to our derivation of wage equation [6] we can now derive

$$w = \frac{1 - \beta}{1 - rr(1 - \beta)}(1 - t) + \frac{\beta}{1 - rr(1 - \beta)} \left(1 + c \frac{F_{UE}}{U} \frac{V}{F_{UE}^v} \right) y. \quad [7]$$

From equation [6] we can see that the equilibrium wage is increasing in y , c and the flat rate benefit b . Increases in c (the cost of posting a vacancy) and b strengthen the bargaining position of the workers and as a result the wage will rise. Workers are likely to bargain over real after-tax wages instead of the nominal wage bill, so taxes increase wage demands by the worker. Therefore direct taxes and social premiums paid by

workers influence the bargaining outcome. Equation [7] shows that the equilibrium wage is decreasing in t and increasing in the replacement rate rr .

In the exposition above we assumed that workers can be either employed or unemployed. In the real world, however, there is a third state, namely workers outside the labor force. Gautier (1997) derives an equation for wage formation where wages are determined as a shared surplus of matches in the labor market, where matches can originate from unemployment as well as from outside the labor force (non-participants). In equilibrium, inflow and outflow in each of the three states has to be equal.

It is assumed that persons outside the labor force have no direct influence on wage formation, so the wage equation is derived by specifying asset equations for unemployed and employed workers and for filled and vacant jobs. Non-participants enter the wage formation process through the inclusion of the quit rate from employment to outside the labor force (F_{EN}/E) in the asset equation for filled jobs and to include F_{NE}^v/V (the flow rate from out of the labor force to employment) in the asset equation for vacant jobs. The asset equations [3] and [4] for filled and vacant jobs can be modified to

$$iW_F = y - w - t - \frac{F_{EN} + F_{EU}}{E} [W_F - W_V] + \dot{W}_F, \text{ and} \quad [3']$$

$$iW_V = \frac{F_{UE}^v + F_{NE}^v}{V} [W_F - W_V] - yc + \dot{W}_V. \quad [4']$$

Based on these asset equations Gautier (1997) then derives the following, slightly modified, wage equation

$$w = \frac{\beta(y + yc - t) \left[i + \frac{F_{EU}}{E} + \frac{F_{UE}}{U} \right] + (1 - \beta)b \left[i + \frac{F_{UE}^v + F_{NE}^v}{V} + \frac{F_{EU} + F_{EN}}{E} \right]}{i + (1 - \beta) \left[\frac{F_{EU} + F_{EN}}{E} + \frac{F_{UE}^v + F_{NE}^v}{V} \right] + \beta \left[\frac{F_{EU}}{E} + \frac{F_{UE}}{U} \right]}. \quad [7']$$

Similar to the bare bones wage equation [7] the interest (i) rate may be omitted from this specification.

Although the theoretical foundation of this flow-based wage curve differs from a traditional wage curve model like, for instance, Oswald (1982), a common feature is that a bargaining process determines the wage level. The main theoretical difference is in the way unemployment influences the bargaining outcome. In traditional wage curve models rising unemployment reduces the union's bargaining power, and hence the wage level, because utility is lower for an unemployed worker than for an employed worker. In search models of the labor market with equilibrium unemployment the causality runs via the employer's bargaining power. Rising unemployment reduces the employer's search costs because of shorter vacancy duration and therefore lowers labor turnover costs, which improves the employer's threat point in the wage bargaining process. The theoretical wage models presented here indicate that there are ample grounds for an explorative econometric analysis of the influence of labor market flows on wage formation.

There appears to be some convergence of evidence in empirical models of wage formation in the Netherlands (see e.g. Van de Wijngaert (1994) for a survey). Increases in consumers plus producers prices are fully passed on to wages as the elasticity of prices to wages is estimated (or set) equal to unity. In most models the same applies to labor productivity; in many models there is a unit, or at least near-unit elasticity between productivity and wages. In other words the wage space is fully used for wage increases. The wage space is defined as the sum of price inflation and labor productivity and has played an important role as a benchmark in wage negotiations in the Netherlands. A recent example of an empirical study on wage formation in the Netherlands using the wage bargaining model is the wage equation included in the JADE-model of the CPB Netherlands Bureau for Economic Policy Analysis (CPB, 2003). This equation is traditional in the sense that unemployment plays (amongst others) a role as determinant for wage formation in a wage curve specification. The equation encompasses empirical knowledge on wage formation in the Netherlands. Its focus is on the tax wedge, and more specifically on the possibilities for employers and workers to pass on increases in direct taxes and social security contributions to customers (through higher prices) and employers (through higher wages) respectively. Like in our empirical model of the next section, the wage equation in JADE is specified as a cointegration and error correction model. It allows for an asymmetric influence of the wedge on the short run, whereas the influence of the wedge on long run wage formation is symmetric although its incidence does not completely fall on workers.

3. Empirical implementation

The flow variables used in our estimates are defined as rates, where a flow from x to y is indicated as $fx_y = F_{xy}/X_{t-1}$. We use the following variables: $feu = F_{EU}/E_{t-1}$ (flow from employment to unemployment, or the lay-off rate) and $fue = F_{UE}/U_{t-1}$ (the flow from unemployment to employment, or the hiring rate). The flow from employment to out of the labor force (the quit rate) is defined as $fen = F_{EN}/E_{t-1}$. It consists of workers who quit their job due to regular and early retirement and workers who leave the labor force due to disability. The other two flow variables in equation [7'] relate to vacancy outflow due to unemployed or persons out of the labor force who find a job by filling a vacancy, $fuev = F_{UE}^v / U_{t-1}$ and $fnév = F_{NE}^v / N_{t-1}$, respectively. The flow data that we use for estimation are constructed using a national accounting method, which is discussed in Broersma, Den Butter and Kock (2000) and Kock (2002). We use annual data and the sample period is 1970-1997 (see the data appendix for details).

Cointegration equation

Equation [7] can be log-linearized using a first order Taylor approximation. This equation serves as the basis for the more complicated wage equation [7'], which we therefore assume can also be log-linearized. Given the limited number of observations available we use the basic cointegration approach and the two-step procedure of Engel and Granger (1987) to specify our empirical model. First the static long-term

equilibrium wage level relation is estimated. In the second step we estimate the associated dynamic error correction specification. Unit roots indicate that the flow variables in our modeling exercise can all be considered as stationary (see the Appendix for unit root tests). The other wage curve variables are all I(1).

Table 1 — Estimation results of the cointegration equation

$\log(w) =$	$0.68 \log y$	$- 0.77 \log(1-t)$	$+ 1.08 \log rr$	$- 1.28 feu$
	(-3.93)	(24.95)	(-3.23)	(11.54)
	$- 5.74 fen + 0.004 (fuev + fnev) - 7.28$			
	(-3.66)	(-2.93)	(-13.32)	

Adjusted $R^2 = 0.99$; ADF = 4.44; PP = 3.83; DW = 1.53; N=26

ADF = Augmented Dickey-Fuller test statistic on stability of the residuals of the regression. PP = Phillips-Perron test statistic on stability of the residuals. Critical value at 5 percent significance level is 3.59. DW is the Durbin Watson test statistic. *t*-statistics are in parentheses. N is the number of observations. Sample period: 1970-1997. Estimation method: OLS

The estimation results of a static long-term equilibrium wage level relation based on a linearized version of equation [7] are reported in Table 1. The outflow out of unemployment turned out not to be significant and was dropped from the final estimation. A test could not reject equality of the coefficients of the two variables that

represent vacancy outflow due to employment inflow from unemployment and due to employment inflow from out of the labor force, and hence these two variables were combined into a single indicator of labor market tension.

The replacement rate, productivity and tax variables all show the correct sign. Higher benefits increase the bargaining power of workers, thereby raising the real wage rate. In fact, the estimated coefficient of 1.08 for the replacement rate suggests full adjustment of wages to changes in the benefit level in the long run: when benefits rise with 1 percentage point over wages in the end this leads to an equal rise in the wage level. Other studies find less than full adjustment; with coefficient values between 0.17 and 0.33 (see Van de Wijngaert (1994), and the previous discussion on the JADE-model). Still, we feel that our specification of a long-run relationship suggests that a constant replacement rate is plausible. It is also consistent with the long-standing Dutch policy of annually adjusting benefits in line with the average nominal wage increase in the private sector in the past year. The long run adjustment coefficient for productivity of 0.68 is broadly in line with the results of other studies, which find coefficients between 0.71 and 1.09. Apparently workers are able to translate more than two-thirds of the productivity increases into higher wages, leaving employers and other capital providers with the remainder. Our estimates seem consistent with the notion that tax cuts support wage moderation (the estimated coefficient for the tax rate of -0.77 is within the range of most other studies). Proponents claim that a policy of tax cuts contributed significantly to employment growth in the Netherlands in the 1980s and 1990s, often suggesting that the tax cuts were part of a coordinated policy effort by the government, unions and employers that enabled unions to moderate wage demands. However, our

results also allow for an alternative interpretation, which suggests that tax cuts stimulated labor supply, which led to lower wage pressure.

Note that the specification of our wage equation is neither a wage curve, nor a Phillips curve. A wage curve explains the wage level by the level of unemployment, or similar, wage growth is explained by the change in unemployment. A Phillips curve, on the other hand, explains wage growth by the level of unemployment. Both the wage curve and the Phillips curve can be seen as the outcome of a wage negotiation process between employers and employees (Blanchflower and Oswald (1990), and Knoester and Van der Windt (1987)). Although we also derive our wages from such a negotiation process, we find instead that the wage level is explained by labor market flows. In fact these flows are employment inflow from unemployment and non-participation and employment outflow to unemployment and non-participation. The underlying implication is that it is labor market flows instead of the change or the level of the unemployment rate that determine the bargaining power of employers and employees. So, our flow-based wage curve is linked to the traditional wage- and Phillips-curve theories since in all three bargaining between workers and employers determine the wage outcome. Another link appears when we focus on the flows into and out of unemployment. With a similar but opposite effect of these flows on the wage level, the wage level in our model would depend on the change in unemployment, or, in terms of growth, wage growth would be explained by the acceleration or deceleration of unemployment growth. It implies that the specification of our model of wage formation differs from both the wage curve specification and from the Phillips curve specification. To what extent does this empirical outcome make sense from an economic perspective? We think it does. For

instance, in case of a recession we observe an increase in the inflow into unemployment, which in our model reduces the bargaining power of workers and therefore cause moderate wage growth. In other words, changes in labor market flows govern wage growth rates instead of changes in (or levels of) labor market stocks. This paper provides both a theoretical and empirical underpinning of this insight.

Dynamic wage equation

We used the cointegration equation to estimate the dynamic wage equation in error correction form (Table 2). We preferred to specify the non-flow indicators in logs to establish a relation between the percentage change in the real wage rate and the percentage change in productivity, taxes and the replacement rate (cf. Graafland (1990a, 1990b)). The indicators of labor market tension are specified as first differences of flow rates. Our specification approach is to move from a general to a specific model. The general model specification includes contemporaneous and lagged dynamic variables and the error correction term from the model in Table 1.

Table 2 — Estimation results of the dynamic wage equation

$$\Delta \log (w) = 0.95 \Delta \log y - 0.73 \Delta \log (1-t) + 0.73 \Delta \log rr - 1.48 \Delta feu_{-1}$$

$$\quad \quad \quad (-2.04) \quad \quad (6.68) \quad \quad (-3.02) \quad \quad (7.26)$$

$$- 4.01 \Delta fen_{-1} - 0.003 \Delta (fuev_{-1} + fnev_{-1}) - 0.65 err_{-1} - 0.006$$

$$\quad \quad \quad (-3.18) \quad \quad (-2.71) \quad \quad (-3.49) \quad \quad (-1.65)$$

Adjusted R² = 0.83; SSR = 0.001; SE = 0.008; DW = 2.13; N=25

SSR is the sum of squared residuals and SE is the standard error of regression. DW is the Durbin Watson test statistic. *err* is the derived residual from the cointegration equation. *t*-statistics are in parentheses. N is the number of observations. Sample period: 1970-1997. Estimation method: OLS.

Our estimation results suggest an almost instant adjustment of wages to changes in productivity, possibly because workers are successfully forward looking with respect to productivity changes and take this into account when negotiating nominal wages. Policy changes might be more difficult to predict, which would explain why wage adjustments in response to changes in the tax rate and the replacement rate take somewhat longer, although with a coefficient of 0.73 the short run adjustment elasticities are still quite high.

The lay-off rate (*feu*) and the flow of workers who leave the labor force (*fen*) push the wage rate down. The results that we find for the lay-off rate are comparable with other

studies for the Netherlands, with long run coefficients between -1.20 and -2.01 (see Van de Wijngaert (1994)). Perhaps the most noticeable result is that the wage impact of the lay-off rate is less than the wage impact of the flow out of the labor force. The latter flow has not been used in an empirical study before, as far as we know. A plausible explanation would be that the average wage rate is lower for workers that are being laid-off than for workers leaving the labor force for retirement or other non-participation because workers in the later group are most likely older, have higher productivity and are more unionized. Another way to see this is to consider the impact of different outflow rates for these two groups over the business cycle. In a boom the lay-off rate will decrease more than the separation rate to non-participation, because most people will make their retirement decision independent of the business cycle. Faced with a smaller stock of unemployed workers to hire from, employers are then forced to hire more expensive non-participants, pushing up the wage rate even further. In a recession the more or less constant outflow of relatively expensive workers to non-participation reinforces the downward wage pressure, which is a result of lay-offs.

The impact of the flow of filled vacancies turns out surprisingly small. The error correction term in the dynamic wage equation is significant and indicates that current wages are corrected for past errors. The coefficient of 0.65 indicates that short run (partial) adjustment is quite fast, although in the JADE model a coefficient value of 0.85 was found which suggests that wages approach their long run levels even more quickly.

4. Conclusion

This paper empirically investigates the influence of labor market dynamics on wage formation. The ‘traditional’ literature models wage formation either as a Phillips curve (where the unemployment rate is a determinant of the change in the wage rate) or a wage curve (where the unemployment rate is a determinant of the wage level). Our specification of the wage curve implies a third possible long-term relationship between wages and economic variables: the wage level is a function of labor market flows and other explanatory variables. In fact, we use the change in the unemployment rate as an explanatory variable in the wage curve, since flows in and out of unemployment determine the change in the level of unemployment in each period.

We find that labor market flows are suitable substitutes for traditional indicators of labor market tightness and hence qualify for inclusion into the wage equation. More specifically, we find that a combination of the outflow from employment to unemployment (lay-offs), outflow from employment to non-participation, and the outflow of vacancies (successful matches) determine the wage level. This corroborates with the theoretical foundation of the wage equation, which describes wage formation as the outcome of a bargaining game between employers and employees, where the relative bargaining power depends on labor market tightness. Our results support the notion that especially in the context of equilibrium search theory labor market flows are relevant for the outcome of the wage bargaining process.

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Data appendix

The flow data used in this paper were constructed using a national accounting system for labor market flows, which is discussed in Broersma, Den Butter and Kock (2000) and Kock (2002). The other data were obtained from the national accounts of Statistics Netherlands (CBS) and the CPB Netherlands Bureau for Economic Policy Analysis (CPB). We use annual data and the sample period is 1970-1997.

Variables

- w real wage rate of workers in enterprises, source: CPB.
- y value added per worker, market sector only, source: CPB.
- rr replacement rate, weighted average of welfare and unemployment insurance benefits, source: CPB.
- t direct taxes on wage income (transaction based), source: CPB.

Appendix: Unit root tests

Bold figure indicates that a unit root cannot be rejected (5 percent confidence level). In the last column we present the order of integration. F_{xy} indicates a flow from x to y, whereas adding v indicates that the flow constitutes filling a vacancy. For example, $fnev$ represents a non-participant filling a vacancy. U and v indicate the stock of unemployed workers and vacancies, respectively. Vo stands for vacancy outflow, and vi stands for vacancy inflow. Fee indicates job-to-job movements. All data are annual.

Table A — Labor market variables

Variable	ADF _t	ADF _c	ADF	PP _t	PP _c	PP	I(x)
Log u	-2.10	-2.71	-0.31	-2.18	-3.60	0.10	
Δ log u	-3.92	-3.59	-3.79	-3.07	-2.58	-2.70	I(1)
Log v	-3.15	-3.19	-0.14	-2.13	-2.53	0.29	
Δ log v	-4.06	-4.03	-4.11	-2.92	-2.87	-2.94	I(1)
Log vo	-2.80	-2.92	-0.09	-2.57	-2.84	0.13	
Δ log vo	-4.16	-4.12	-4.24	-4.61	-4.47	-4.57	I(1)
Log vi	-2.79	-2.95	-0.00	-2.37	-2.68	0.17	
Δ log vi	-3.96	-3.89	-4.00	-4.52	-4.32	-4.40	I(1)
Log fee	-2.26	-2.29	0.17	-2.18	-2.19	0.21	
Δ log fee	-2.57	-2.60	-2.66	-4.36	-4.40	-4.46	I(1)
Log feev	-3.15	-2.28	-0.42	-2.95	-2.35	-0.25	
Δ log feev	-4.66	-4.61	-4.72	-5.19	-5.01	-5.14	I(1)
Log feu	-3.78	-1.82	-0.72	-3.16	-2.35	-1.43	

Variable	ADF _t	ADF _c	ADF	PP _t	PP _c	PP	I(x)
$\Delta \log fue$	-3.78	-3.87	-3.92	-4.02	-4.15	-4.21	I(1)
Log fue	-1.77	-2.73	-2.68	-2.08	-3.30	-3.33	
$\Delta \log fuev$	-3.76	-3.16	-3.28	-5.53	-4.61	-4.62	I(1)
Log fuev	-2.52	-2.68	-0.83	-2.11	-2.29	-0.72	
$\Delta \log fuev$	-3.05	-3.07	-3.15	-4.03	-4.03	-4.11	I(1)
Log fen	-1.19	-1.92	-0.33	-1.19	-2.01	-0.36	
$\Delta \log fen$	-3.86	-3.05	-3.10	-6.09	-5.25	-5.34	I(1)
Log fine	-3.48	-1.98	-0.61	-3.25	-2.20	-0.89	
$\Delta \log fine$	-5.40	-5.54	-5.50	-6.57	-6.64	-6.69	I(1)

Table A (continued)

Variable	ADF _t	ADF _c	ADF	PP _t	PP _c	PP	I(x)
Log fnev	-2.86	-2.91	-1.26	-3.14	-3.48	-1.60	
Δ log fnev	-5.08	-4.90	-4.87	-6.67	-6.40	-6.38	I(1)
Log fun	-1.73	-2.12	-0.70	-1.90	-2.76	-0.71	
Δ log fun	-3.38	-2.85	-3.03	-3.79	-3.02	-3.12	I(1)
Log fnu	-2.46	-1.96	0.35	-2.96	-2.63	0.61	
Δ log fnu	-4.25	-4.25	-4.33	-6.48	-6.54	-6.64	I(1)
Critical value, $\alpha=5\%$, n=26	-3.59	-2.98	-1.95	-3.59	-2.98	-1.95	

Unit root tests: Augmented Dickey-Fuller with trend (ADF_t), Augmented Dickey-Fuller with constant (ADF_c), Augmented Dickey-Fuller with no trend and no constant (ADF), Phillips-Perron with trend (PP_t), Phillips-Perron with constant (PP_c), Phillips-Perron with no trend and no constant (PP).

Table B — Other variables

Variable	ADF _t	ADF _c	ADF	PP _t	PP _c	PP	I(x)
log w	-3.63	-2.73	0.33	-4.23	-8.81	2.79	
Δ log w	-1.32	-1.48	-1.80	-1.27	-1.66	-2.25	
ΔΔ log w	-4.54	-3.87	-3.38	-4.81	-4.72	-4.63	I(2)
log y	-2.43	-2.74	3.06	-2.54	-4.35	5.63	
Δ log y	-4.18	-3.19	-1.38	-5.12	-4.15	-2.05	I(1)
log t	-2.40	-2.69	-1.30	-2.51	-3.34	-1.82	
Δ log t	-3.53	-3.34	-3.20	-4.59	-4.38	-4.21	I(1)
log rr	-2.63	-1.44	-0.26	-1.93	-1.06	-0.17	
Δ log rr	-3.78	-2.30	-2.65	-2.85	-2.31	-2.36	I(1)
Critical value, α=5%, n=26	-3.59	-2.98	-1.95	-3.59	-2.98	-1.95	

Unit root tests: Augmented Dickey-Fuller with trend (ADF_t), Augmented Dickey-Fuller with constant (ADF_c), Augmented Dickey-Fuller with no trend and no constant (ADF), Phillips-Perron with trend (PP_t), Phillips-Perron with constant (PP_c), Phillips-Perron with no trend and no constant (PP).