Search and Matching Model in the Short-Run
version 9.1 *

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1 Introduction

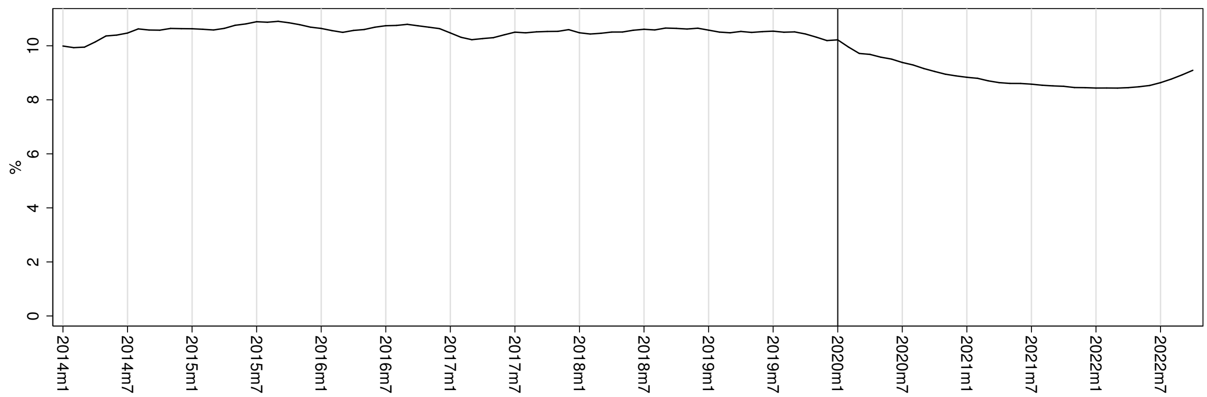
Since COVID-19, the South Korean government started a quarantine policy that reduced temporary foreign workers (TFW). The number of TFWs in the manufacturing sector was exogenously reduced by 2% until 2022m3 (Figure 1). After lifting the quarantine policy around 2022m3, the number started to increase. Figure 2 shows the number of E9 visa workers, one of the major workers among TFWs. This figure shows a trend similar to the previous figure.

Jeong (2022) (work in progress) studied the event of TFW reduction using the difference in difference (DD) approach. He found that in the short-run, the reduction in TFW caused a *surge* in the vacancy rate. Specifically, when 2% of the workers decrease, the vacancy rate increases by 0.6815%p. Panel B of Figure 7 of his paper shows a monthly DD result. The vacancy rate started to increase from the onset of COVID until 2022m3. Since 2022m3, it has started to decrease due to the lifting of the quarantine policy.

It is interesting to study the theoretical mechanism of the vacancy rate *surge* when there was an exogenous reduction in the labor force. An immediate theory that can be thought of is the search and matching model (DMP model). However, the standard search and matching model predicts that the vacancy rate would *go down* when the population continues to decrease (negative birth rate). This is because the standard search and matching model assumes a highly fluid capital (long-run). There are various versions of search and matching models, including in Howitt and Pissarides (2000), Elsby et al. (2015), Diamond (1982), and Mortensen and Pissarides (1994), but all these versions

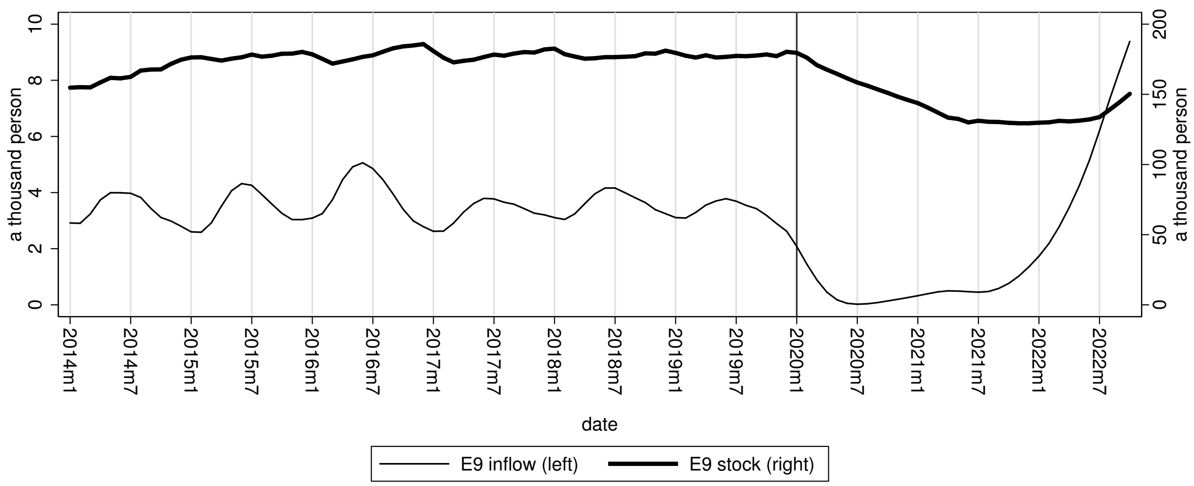
[0]It is possible to replicate all of the results using Matlab codes below:
https://raw.githubusercontent.com/jayjeo/public/master/LaborShortage/SearchandMatching.zip
Download the zip file, unzip to the desired location, and open Readme.txt

Figure 1: Proportion of Temporary Foreign Workers (TFW)



Source: Korea Immigration Service Monthly Statistics & Survey on Immigrant's Living Conditions and Labour Force

Figure 2: E9 Visa Workers

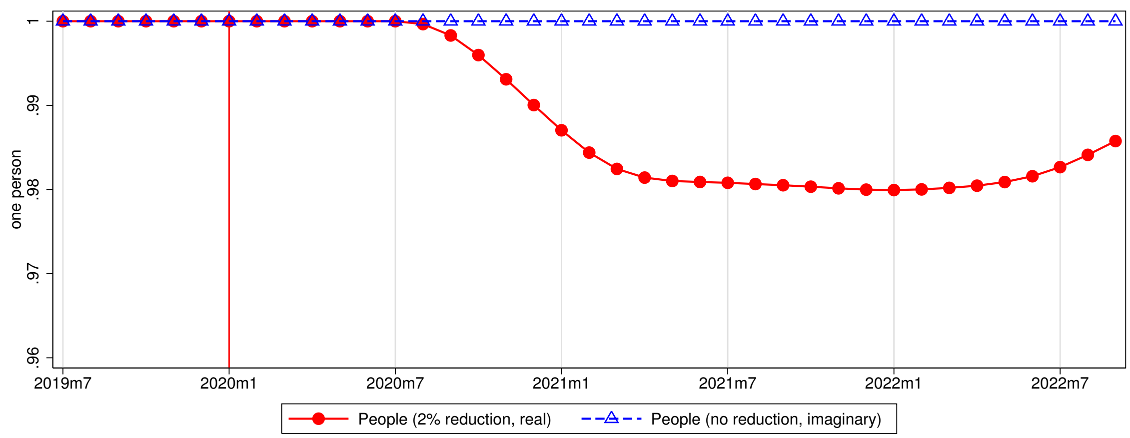


Source: Employment Permit System (EPS)

implicitly assume fluid capital. This is true even in instances of dynamic analysis (out of steady-state). Dynamic analysis studies how an out of steady-state converges with a unique path to create a new steady-state equilibrium under conditions of fluid capital.

Therefore, to explore why the vacancy rate *surged in the short-run*, this paper will adjust the standard search and matching model to fit in the short-run. Using this short-run model, the paper will simulate the vacancy rate, the unemployment rate, and the wage. The simulation only focuses on the manufacturing sector in South Korea. Also, it will use data spanning from 2019m1 (onset of COVID) through 2022m9. This time period includes the lifting of the quarantine policy, when the number of people started to increase again. The simulation will compare real and imaginary situations as shown in Figure 3: 1) the real situation where the population decreased by 2% and 2) the imaginary situation where the population remained constant.

Figure 3: Number of Population



The model departs from the standard search and matching model. Like the standard model, the model has a dynamic path condition for *unemployment rate* **(denote Upath)**. What is new to this model is that it also has a dynamic path condition for *vacancy rate* **(denote Vpath)**. This vacancy path should exist since the model no longer allows firms' free entry and exit. In the standard model for long-run analysis, any number of firms can enter or exit in a single period (jump).

The model no longer has the Beveridge curve (BC). BC describes a steady-state equilibrium condition for the unemployment and vacancy rate. Therefore, BC finds a condition that is stable over time, unless other shocks arrive. In contrast, in this paper, the unemployment and vacancy rates keep moving following the paths (Upath and Vpath).

Although the model does not have BC, there is a simple rule: the sum of the vacant positions and the matched positions should be equal to the total number of positions by firms. In other words,

$$\text{Positions}_t = v_t L_t + (1 - u_t) L_t \tag{PO}$$

, where Positions_t is the total number of positions, v_t is the vacancy rate, and u_t is the unemployment rate. L_t is the total number of people on the market, normalized to one. Positions_t, time variant parameter, is acquired from the ex-post value of the vacancy rate and the unemployment rate ($\text{Position}_t = v_t L_t + (1 - u_t) L_t$). Equation PO will mainly determine the simulation results of the vacancy and the unemployment rate. Therefore, using Positions_t is a strong assumption. However, Positions_t alone cannot simulate the rate of vacancy and unemployment at all. The simulation needs Equations Upath and Vpath.

It is worth noting that Positions_t is not allowed to 'jump'. Moreover, it is not fixed even in the short-run. Its value slowly changes. If Positions_t represents the actual number of 'establishments', then its change in the short-run may sound strange. However, the search and matching model defines that **a** firm is matched to **a** person. Therefore, the number of 'positions' may change even in the short-run.

Meanwhile, the model acquires the wage curve (WC) in the same way as the standard search and matching model. The equation is more complicated because the assumption of free entry and exit ($V = 0$) is invalid. In the long-run, when the free entry and exit condition holds, $V = 0$ is valid. Then Equations J and V (defined in the next section) produce the Job Creation Curve (JC). However, in the short-run model, such a JC does not exist.

Table 1 summarizes the comparison between the short-run and long-run model.

Table 1: The comparison between short and long run models

Short-run		Long-run
PO	$\Rightarrow$	Holds, but meaningless
BC does not hold	$\Rightarrow$	**BC** holds in steady-state
Upath	$\Rightarrow$	**Upath** holds in dynamic state
Vpath	$\Rightarrow$	Does not hold anymore
WC is more complicated	$\Rightarrow$	**WC** holds in steady-state
JC does not exist	$\Rightarrow$	**JC** holds in steady-state

With proper parameter calibration, the simulations predict the vacancy and unemployment rates well enough. The simulation shows that the vacancy rate surged by 0.5405%p when the population decreased by 2%. This value is slightly lower than the DD result of 0.6815%p (Jeong, 2022) (work in progress). The intuition of the rise in vacancies is that *in the short run*, firms cannot fully adjust their positions. The simulation shows that the unemployment rate drops by 1.3408%p when the population decreases by 2%. The intuition is that the unemployed become smaller when the population is smaller.

Meanwhile, the simulation shows that the wage increased 24.61% from the wage of the constant population. However, Panel G of Figure 7 in Jeong (2022) showed using the DD approach that the wage difference is insignificant. This contradicts the wage simulation. Moreover, the wage simulation does not predict the real value well. The real value of the wage is sticky and stable, whereas the simulated wage derails it.

To better predict the wage, the model adopts a constant wage model by Hall (2005). He presented a criterion within which a constant wage is possible. However, one shortcoming of his model is that it does not explain why a constant value has to be specifically a specific wage value. Therefore, I also present another sticky wage structure.

Finally, I present the simulation result for the long-run. The model is just the standard search and matching model. From the long-run perspective, the 2% reduction in population was a one-time event, which does not happen constantly. Therefore, the Beveridge curve (BC) in the long-run returns to the original level of pre-COVID, because the birth rate is zero. As a result, the vacancy and the unemployment rate will be the same as in a pre-COVID state, as if nothing had happened to the population (assuming that the labor demand is the same as pre-COVID).

In the next section, I will briefly introduce the dataset that this paper uses. Then, in Section 3, I will carefully explain the short-run model and results. In Section 4, I will explain the long-run model and its results. Section 5 discusses the contributions and shortcomings of this paper.

2 Data

This paper mainly uses two datasets: The Labor Force Survey at Establishments (LFSE), and the Economically Active Population Survey (EAPS). LFSE is a Korean version of JOLTS in the USA. It replicates the definitions and methods exactly from JOLTS. One big difference is that it provides more variety of variables by industry sector. From LFSE, this paper acquires the vacancy rate (v), the number of total employees in each month (Emp), wage (w), the number of newly matched people in a month (Matched), and the number of separated people in a month (Exit).

EAPS is a Korean version of CPS in the USA. EAPS also replicates CPS to almost the same variables and structures. Using this dataset, this study acquires the unemployment rate in the manufacturing sector.

There are a few minor datasets that the paper uses. First, the Monthly Survey of Mining and Manufacturing (MSMM) provides labor productivity (p). Second, the paper uses three datasets, EPS, KIMS, and SILC, to acquire the information for the exogenous reduction of TFWs due to COVID-19. The EPS provides the monthly number of E9 and H2 visa workers staying in South Korea. KIMS provides monthly information for the number of temporary and permanent residents by visa type. While EPS provides the number of workers, KIMS only provides the number of visitors and residents. Finally, SILC is a yearly sample survey that resembles the Economically Active Population Survey (EAPS), a Korean version of the Current Population Survey (CPS) in the USA. SILC provides a variety of information about foreigners and naturalized citizens. Specifically, it provides the surveyees' employment status. Therefore, it is possible to calculate the employment and unemployment rates. Combining these EPS, KIMS, and SILC, I could generate the exogenous monthly reduction of temporary foreign workers.

3 The Short-run Model

3.1 Environment

The short-run model adopts the concept of the standard search and matching model. Unless otherwise noted, all notation is the same as Howitt and Pissarides (2000). The model uses a discrete-time with a monthly frequency. The matching technology is given by $m(u, v) = av^{\alpha}u^{1-\alpha}$. Therefore, the total number of matches is $m_t L_t$. For convenience, denote $\theta \equiv \frac{v}{u}$, and $q \equiv a\theta^{\alpha-1}$. Therefore, the matching arrival rate per firm is q, while the matching arrival rate per person is θq.

The population (L_t) is normalized to one. For instance, the total number of unemployed is $uL = u$. When there is a 2% reduction in population, L_t is reduced from one to 0.98. A large measure of firms each have one position. This position is either vacant or matched.

When a vacant position is not filled, the firm must pay a search cost equal to pc. When the firm meets an unemployed, a job is formed, and the firm pays the wage (w) to the worker. This wage is determined by Nash bargaining when the two parties first meet. Let η represent the bargaining power of workers.

The destruction rate of existing jobs (λ) is exogenous. Once a shock arrives, a match is terminated. Subsequently, the worker becomes unemployed, and an unemployed person receives a benefit of $z > 0$ per month. In addition, when a matched job is destroyed, the position becomes vacant. Some vacant positions can exit the labor market, but not all can do. In detail, the number of positions in the labor market will be determined by a variable, Position$_t$. In this setting, the number of positions is neither allowed to 'jump' indefinitely nor to stay constant. If a vacant position remains in the market, it must try to find another match paying the search cost, pc.

The total number of endogenous variables is three ($w, u,$ and v). Like the standard model in dynamics, the unemployment rate follows a predetermined path:

$$u_{t+1}L_{t+1} = u_tL_t - m_tL_t + \lambda_t(1-u_t)L_t. \tag{Upath}$$

Unlike the standard model, the vacancy rate also has to follow a predetermined path:

$$v_{t+1}L_{t+1} = v_tL_t - m_tL_t + \lambda_t(1-u_t)L_t. \tag{Vpath}$$

By natural identity, Equation PO exists:

$$\text{Position}_t = v_tL_t + (1-u_t)L_t. \tag{PO}$$

Since Position_t and L_t are known parameters, Equation PO is the relationship between v_t and u_t. This relationship is an upward line, unlike the Beveridge curve (downward curve). Equation PO is similar to the market tightness (θ), which also defines the upward slope in the space of v_t and u_t.

Equation PO determines mostly the simulation results of the vacancy and unemployment rates. For example, the U-shaped simulation result of around 2020m6 in Figure 4 is due to Equation PO. Furthermore, Position_t is a parameter that acquires its value from ex-post values of v_t and u_t. Therefore, Position_t a strong assumption. Nevertheless, Positions_t alone cannot simulate anything: Equation Upath and Vpath are crucial for the model to work.

Meanwhile, the following equations are the same as those in the standard model. Let me omit the time subscript for convenience of notation.

$$V = -pc + \beta\big(qJ + (1-q)V\big) \tag{V}$$
$$J = p - w + \beta\big(\lambda V + (1-\lambda)J\big) \tag{J}$$
$$W = w + \beta\big(\lambda U + (1-\lambda)W\big) \tag{W}$$
$$U = z + \beta\big(\theta qW + (1-\theta q)U\big) \tag{U}$$

, where β is a time discount factor. Nash bargaining solution yields Equation Nash.

$$\arg\max_w (W-U)^{\eta}(J-V)^{1-\eta}$$
$$\Rightarrow \frac{W-U}{\eta} = \frac{J-V}{1-\eta} \tag{Nash}$$

A combination of Equations V, J, W, U, and Nash produces Equation WC. Since the firms' free entry and exit assumption does not hold, V may not be zero, which complicates

Equation WC as shown below:

$$w = \frac{\eta p M H + (1-\beta)(1-\eta) z M B + (1-\beta)\big(cB - \beta q\big)\eta p H}{MH - (1-\beta)(1-\eta)\beta\theta q M - (1-\beta)\beta q \eta H} \tag{WC}$$

, where

$$B \equiv (1-\beta+\beta\lambda)$$
$$M \equiv (1-\beta+\beta q)B - \beta^2\lambda q$$
$$H \equiv (1-\beta+\beta\theta q)B - \beta^2\lambda\theta q$$

The parameter $\beta = 0.9951$ is almost close to 1. Letting $\beta = 1$ simplifies Equation WC to $w_t = \eta p_t$. Consequently, one may guess that the simulated wage will depend only on p_t. However, this is not true. The shape of the simulated wage is mainly from θ_t, which is determined by v_t and u_t.

In summary, Equations PO, Upath, and Vpath determine v_t and u_t, which in turn decides θ_t. Then θ_t decides the wage. Notice that this sequence is in reverse order of the standard matching model. In the standard matching model, Equation WC and JC decide θ_t and wage first, and then θ_t and Equation BC determine v_t and u_t.

3.2 Calibration

Since deriving explicit solutions is impossible, a numerical approximation is necessary, which first requires proper calibration. The labor productivity (p_t) and the number of people on the market (L_t) are from official data (time variants). The remaining parameters are time invariants. They are calibrated as shown in Tables 2 and 3. **The bold texted values are what this paper will use**.

Table 2: Parameters

Parameter	Meaning	Value	Source
β	Discount factor	**0.995**	Hall (2005) and Shimer (2005)
		0.997	Thomas (2008)
c	Firm's search cost	**0.986**	Hall (2005)
z	Unemployment benefit	**0.4**	Hall (2005) and Shimer (2005)
		0.71	Hall and Milgrom (2008) and Pissarides (2009)
η	Worker's bargaining power	**0.72**	Shimer (2005)
		0.5	Gertler and Trigari (2009)

Also, the calibration results for a, α, and λ are presented in Table 3. Meanwhile, a, α, and λ can be calibrated so that the simulation results closely correspond to the real ex-post values ($a = 0.180$, $\alpha = 0.147$, and $\lambda = 0.012$). Then it matches the real output well (Figures 4 and 5). In these figures, the simulation result (red line with circle marks) follows well the real output (black line). However, these calibrated values are very different from the calibration values in the literature, as shown in Table 3. Let me denote these calibrations as **'bad calibration'**.

Table 3: Parameters

Parameter	Source	Good or bad	Value
a	Shimer (2005)		1.355
	Gertler and Trigari (2009)		1
	Hall (2005)		0.947
	Calibration by author	Good calibration	**0.665**
	Calibration by author	Bad calibration	0.180
α	Thomas (2008) and Diamond and Blanchard (1989)		0.6
	Gertler and Trigari (2009)		0.5
	Petrongolo and Pissarides (2001)		0.5
	Gertler et al. (2008)		0.5
	Shimer (2005)		0.28 [1]
	Calibration by author	Good calibration	**0.319**
	Calibration by author	Bad calibration	0.147
λ	Blanchard and Galí (2010)		0.042 [2]
	Fujita and Ramey (2007)		0.039
	Gertler and Trigari (2009)		0.035
	Hall (2005)		0.034
	Shimer (2005)		0.034
	Calibration by author	Good calibration	**0.034**
	Calibration by author	Bad calibration	0.012

Meanwhile, a regression method can calibrate a, α, and λ. This calibration result is provided in Table 3, which will be used primarily in this paper. Let me denote these calibrations as **'good calibration'**. The calibration method is explained as follows: Denote the total number of people working as 'Emp'; the number of people newly matched in each month as 'Matched'; the number of people separated each month as 'Exit'. The LFSE dataset, which is the Korean version of JOLTS, provides all of these variables as monthly data. Also, denote the monthly matching rate as $m(u, v)$; the total number of people as L, and the separation rate as λ.

First, I can easily get λ as follows: Notice that Exit $= \lambda(1-u)L$. Therefore, $\lambda =$

[2]0.72 that appears in Shimer (2005) is in terms of u, not v. Therefore, $1 - 0.72 = 0.28$ in terms of v.

[2]0.12 (quarterly value) is transformed to 0.042 (monthly value) by the following calculation: solve($x + (1-x)x + (1-x)^2x = 0.12$), then $x = 0.042$

Figure 4: Vacancy rate (with bad calibration)

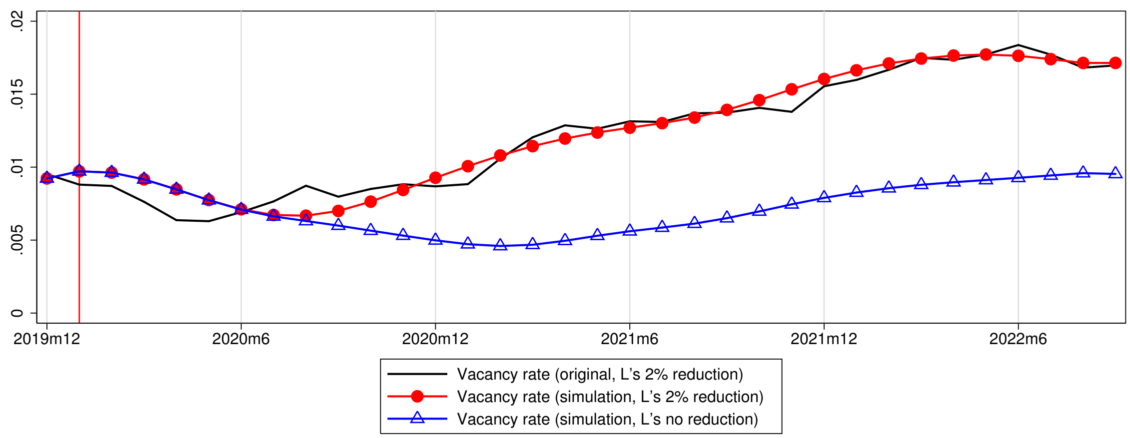
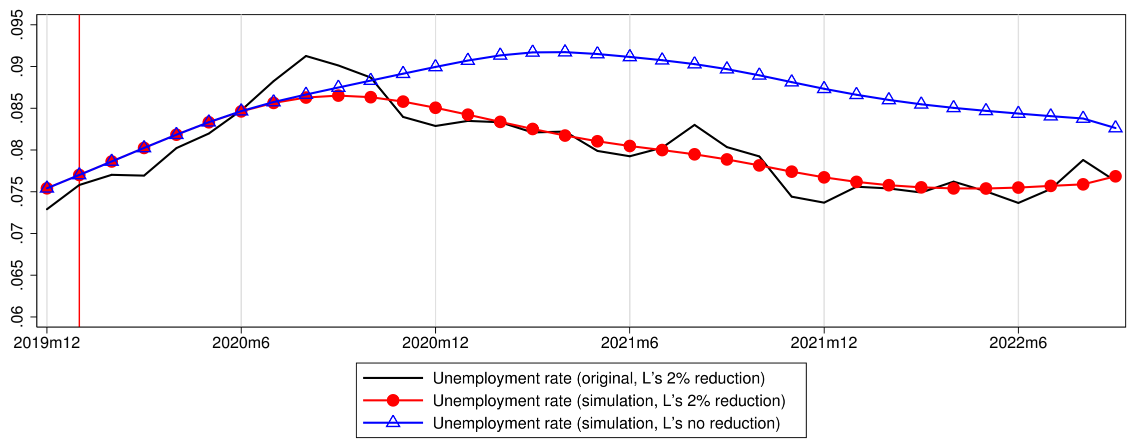


Figure 5: Unemployment rate (with bad calibration)



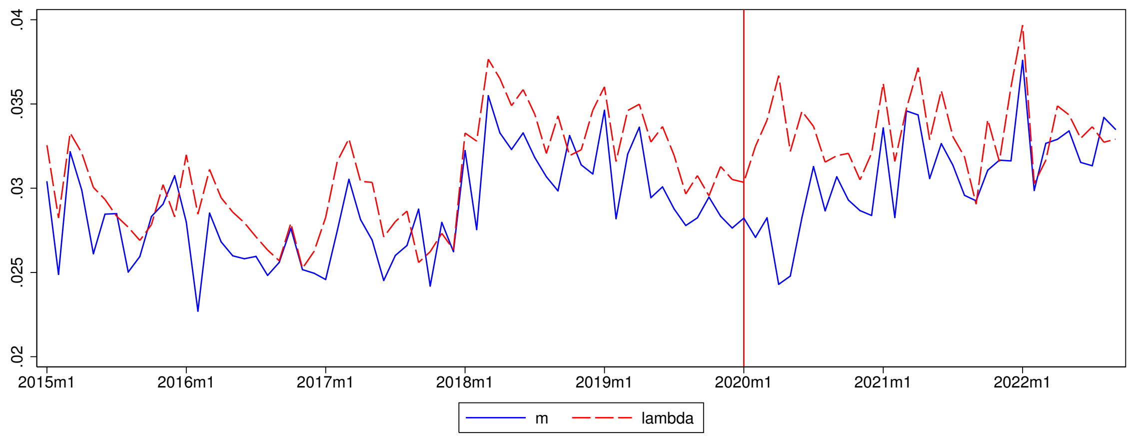
$\frac{\text{Exit}}{(1-u)L}$. Second, I can get L and $m(u,v)$ as follows: notice that Emp $= (1-u)L$, therefore $L = \frac{\text{Emp}}{(1-u)}$. Since mL = Matched, therefore $m = \frac{\text{Matched}}{L}$. Figure 6 shows $m(u,v)$ and λ by month. In the last two years, λ fluctuated mostly between 0.033 and 0.035. Therefore, let me calibrate that $\lambda = 0.034$, as time invariant variable.

The following explains how to calibrate a and α, which appear in Equation 1. Putting logs in this equation, I get Equation 2. I have all the values in the equation except $\ln a$ and α. Using a non-linear least-squares estimation [3] using Equation 2, I get $\ln a = -0.4074$ and $\alpha = 0.3187$. Therefore, $a = 0.6653$.

Although the value of a I get is little bit smaller than those in literature, they are close. This difference might be due to the different environments. My result is about the

[3]In Stata, the regression command would be: nl $(\ln m = (\ln a = 1) + ((\alpha = 0.235) * \ln v) + ((1 - (\alpha = 0.235)) * \ln u))$. Download the zip file from Github, and run calibration.do for replication.

Figure 6: m and λ



South Korean manufacturing sector. In the remaining sections, I will use the values of **'good calibration'**.

$$m = av^{\alpha}u^{1-\alpha} \tag{1}$$

$$\ln m = \ln a + \alpha \ln v + (1-\alpha)\ln u \tag{2}$$

3.3 Simulation Results

Figure 7 is about the vacancy rate. In the figure, the black line is the real outcome; the red line with circled marks is the simulation when the population decreased by 2%; the blue line with triangle marks is the simulation when the population remained constant. Similarly, Figure 8 is about the unemployment rate, and Figure 9 is about the wage.

Figures 7 and 8 use the 'good calibration' values. On the contrary, Figures 4 and 5 use the 'bad calibration' values. The figures show that the former is less accurate than the latter. Although less accurate, I will use the former ('good calibration'). This is because its calibration values are closer to those in the literature and thoroughly calculated the results using the actual data.

In Figure 7, when the population decreases by 2% (red line), the vacancy rate increases compared to when the population is constant (blue line). As of 2022m1, the difference between the two vacancy rates is 0.5405%p. This value is lower than the DD result of 0.6815%p (Jeong, 2022). However, they are comparable.

When the population drops by 2%, the unemployment rate drops by 1.3408%p (Figure 8 at 2022m1). The intuition is that when the population is smaller, the unemployed become smaller. When the population drops by 2%, the wage increases 24.61% from the

Figure 7: Vacancy rate (with good calibration)

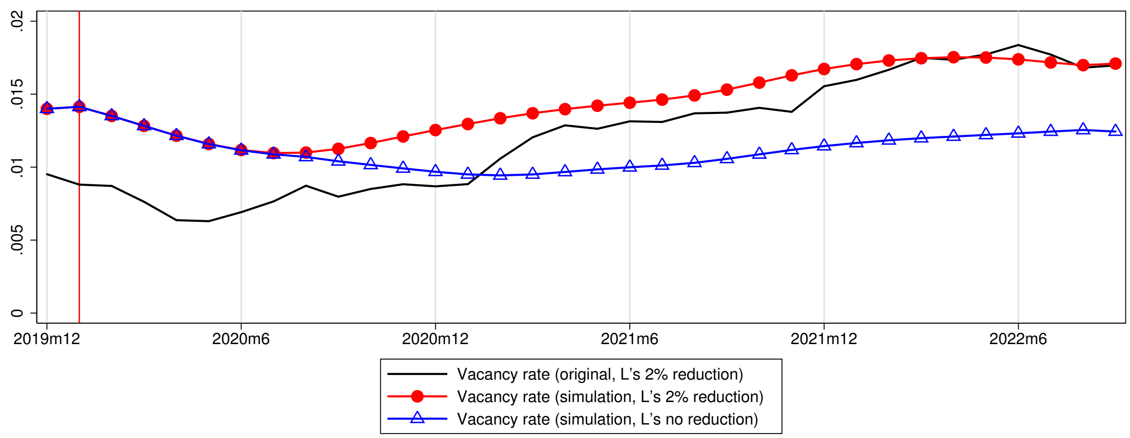
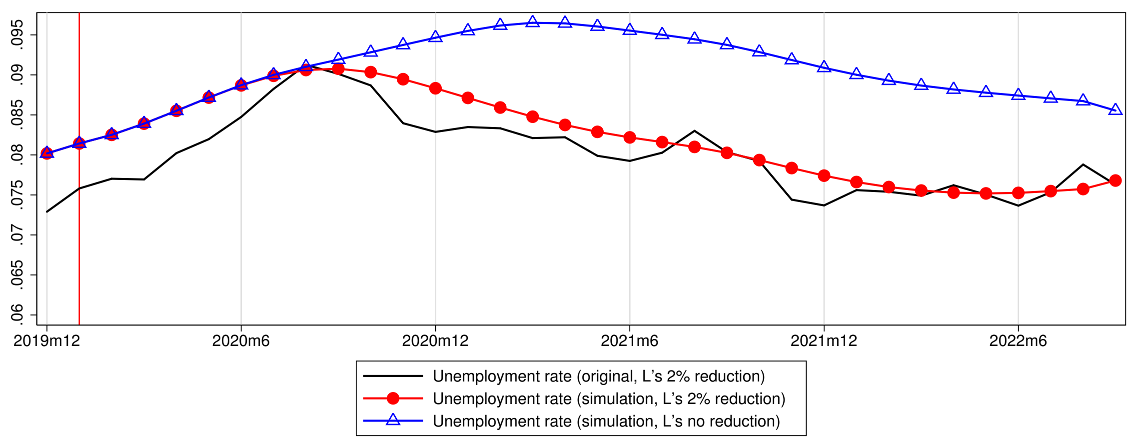


Figure 8: Unemployment rate (with good calibration)



wage of the constant population (Figure 9 at 2022m1). The intuition is that the tighter market leads to a higher wage. However, the real wage(black line) seems sticky, and the simulated wage derails it.

Furthermore, the wage simulation is inconsistent with a DD analysis by Jeong (2022) (work in progress). The DD result showed that the wage differences are insignificant, while the simulation shows a significant difference. Therefore, alternative models are necessary for wage simulation.

One solution is a constant wage model by Hall (2005). He showed that any constant wage that satisfies Equation 3 is Nash equilibrium. In his model, the Nash bargaining condition does not exist, which in turn, the Wage curve (WC) does not exist. Therefore, Equation JC and the constant wage determine θ_t. Meanwhile, notice that the Nash bargaining solution in the standard matching model is one of the solutions of the Nash

Figure 9: Constant Wage by Hall (2005))

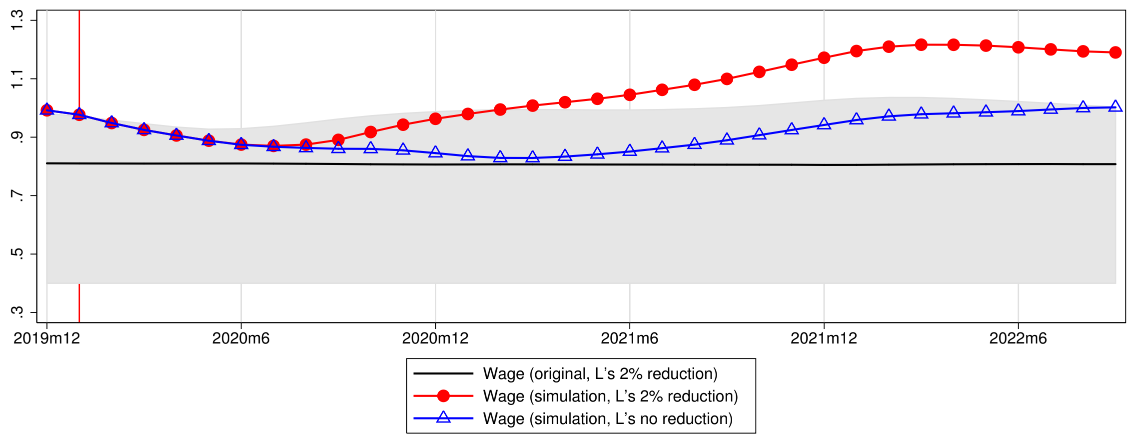
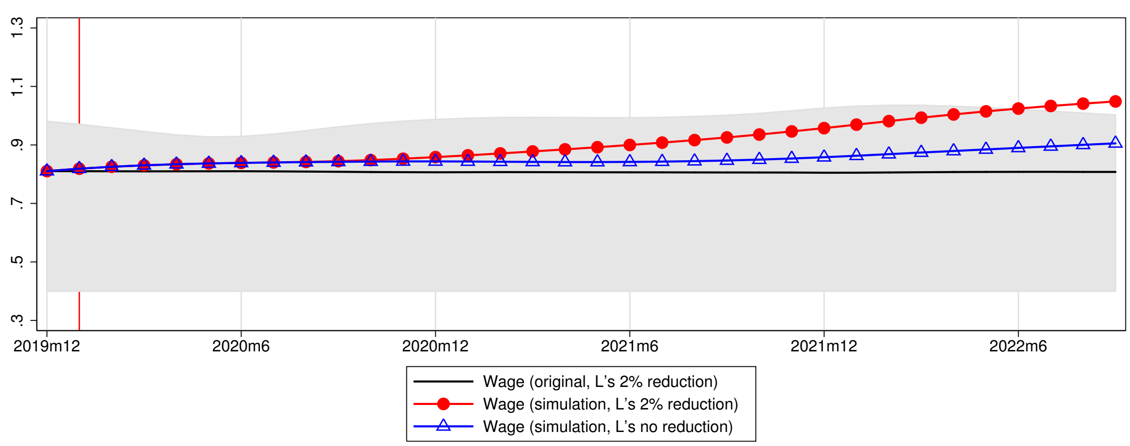


Figure 10: Sticky Wage ($\sigma = 0.99$)

Figure 11: Sticky Wage ($\sigma = 0.95$)



equilibrium in Hall (2005). Also, note that a wage in his model is constant only between the contracting party. Another contracting party in the next month may have a different wage contract, which will be constant throughout their matching. Therefore, the wage in his model is neither perfectly constant nor as volatile as the standard matching model. In the standard model, the wage is constantly updated every period, leading to a more unstable wage.

$$z \leq w \leq \min_s [1 - \beta(1-\lambda)] \tilde{J}_s \tag{3}$$

$$z \leq w \leq p \tag{4}$$

Since my model in this paper does not have multiple probability states, s, Equation 3 simplifies to Equation 4. Intuition is straightforward. Any constant wage greater than the unemployment benefit and smaller than the labor productivity is a Nash equilibrium. In Figure 9, any constant wage within the gray area is the Nash equilibrium. This wage model simulates much better than the previous model.

One shortcoming of this constant-wage setting is that a constant value —for example, 0.81 in Figure 9— is arbitrary. For instance, Hall (2005) is silent about why a wage should be specifically at 0.81 —when there are numerous other candidates for the wage in $z \leq w \leq p$.

Therefore, I propose another simple solution, which imposes weights on the current and past wages as follows:

$$w_{t+1} = \sigma w_t + (1-\sigma)\mathrm{RHS}_t \tag{5}$$

, where RHS_t is the right-hand side of Equation WC, and σ is a weight —0.99 for example. This sticky wage setting shows a good result. Figure 10 is the simulation result when σ is 0.99; Figure 11 is the result when σ is 0.95. According to these two figures, $\sigma = 0.95$ is not large enough to achieve a good result.

It is important to note that this sticky wage setting (as well as the constant wage setting by Hall (2005)) does not affect the simulation results of the vacancy and unemployment rates in this paper. This is because the model determines the vacancy and the unemployment rates prior to determining the wage. Figures 7 and 8 are exactly the same as the simulation results from the sticky wage setting.

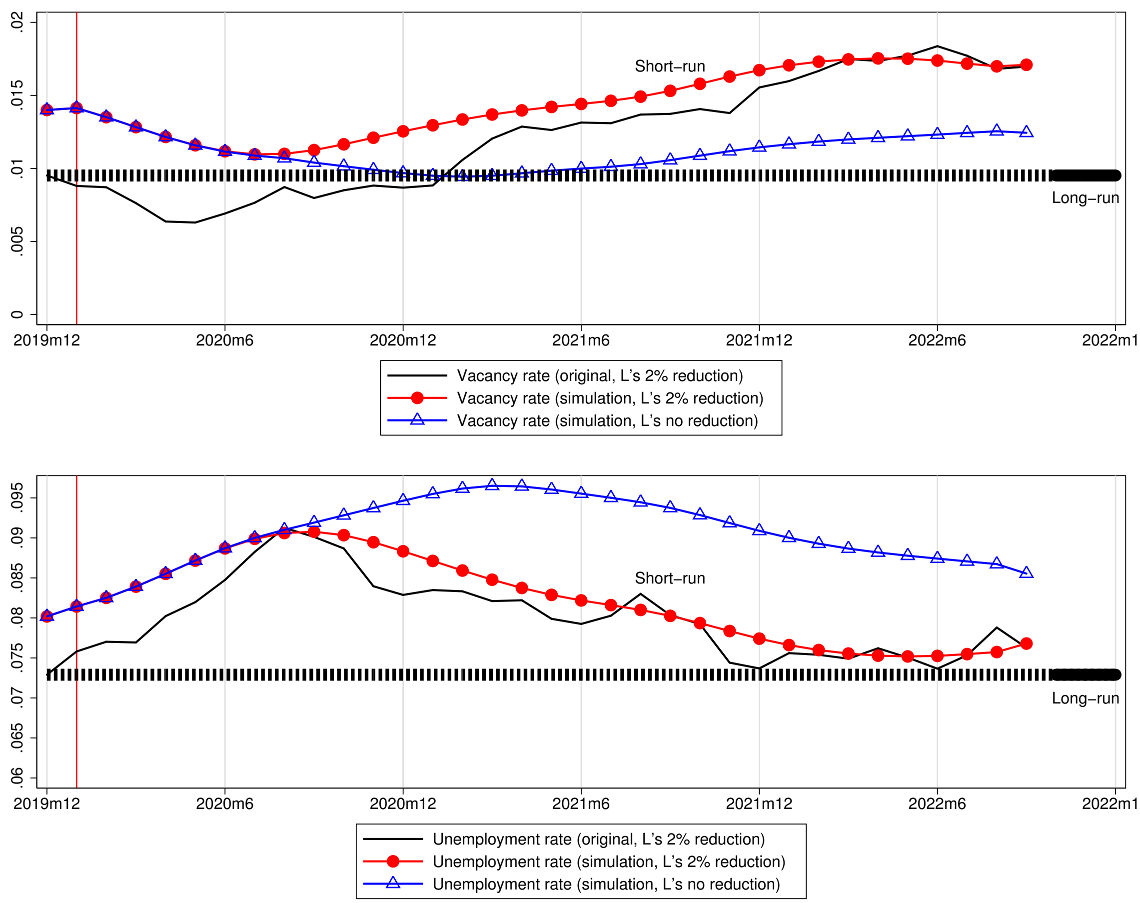
4 The Long-run model

The long-run model in this paper is the same as the standard model in Howitt and Pissarides (2000) (Ch.4), which has a birth rate. If the population continues to decrease in the long run, the vacancy rate and the unemployment rates will be lower. This result is due to the Beveridge curve (BC) moving closer to the origin (the negative birth rate).

In contrast, if the 2% population reduction is a one-time event (so that it stops decreasing), then BC returns to the original level (the zero birth rate). Then the vacancy and unemployment rates will be the same between the decreased and constant populations. Since the 2% population reduction should be considered a one-time event, the vacancy and unemployment rate will be the same as if nothing had happened to the population.

Suppose that labor productivity and firms' labor demand are the same between 2019m12(pre-COVID) and long-run. Then in the long-run, the vacancy and unemployment rates would be the same as in 2019m12. Figures 12 depict it.

Figure 12: Long-run simulation



The intuition is that, in the short run, firms cannot adjust their positions, resulting in a vacancy surge. In contrast, in the long-run, firms know the more challenging matching conditions and reduce the number of positions accordingly.

5 Conclusion

First, this paper has a policy implication. Some might argue that high vacancies have recently been an issue because of the labor demand side (production), not because of the reduction of foreign workers. Indeed, the paper showed that some increase in vacancies is due to the labor demand side. However, the paper also showed that the reduction of foreign workers exacerbated this surge. Therefore, accepting TFWs is essential for manufacturing firms to survive.

Second, this paper contributes that the search and matching model can explain the increase in vacancies *in the short-run.* The standard models could not explain this vacancy surge because they focus on the long run. Pointing out that the vacancy can move in the reverse direction in the short run is also a contribution to the literature.

Third, the DD result and this simulation result are comparable. The DD result in Jeong (2022) is that when 0.02 workers decrease, the vacancy rate increases by 0.6815%p. Meanwhile, in this paper, when 2% of the population decreases, the vacancy rate increases by 0.5405%p. This comparability ensures that both studies are valid and worth reading.

This paper clearly has weaknesses. As noted several times, Positions$_t$ in Equation PO is a strong assumption. Positions$_t$ is acquired by the ex-post value of the vacancy and unemployment rate ($v_t L_t + (1 - u_t)L_t$). Therefore, the simulation results are not induced under a completely autonomous environment. Instead, in large part, those are guided by Positions$_t$. However, Positions$_t$ alone cannot simulate anything. Furthermore, without EquationsUpath and Vpath, the simulation poorly matches the actual outcome. Therefore, a proper setting of Equations Upath and Vpath is essential for accurate simulation.

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