Immigration, Labor Shortages, and Labor Market Dynamics

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December 1, 2025

Abstract

Immigration has become a primary driver of U.S. labor force growth. We present three new empirical findings that highlight the interlinkages between immigration, labor shortages, wage growth, and job openings during the high-immigration period from 2020 to 2024. The textbook search and matching model of the labor market generates highly counterfactual labor market dynamics in wages and labor market tightness resulting from an immigration surge. We extend the framework to incorporate complementarities between native and immigrant workers, along with Leontief-type labor market shortages, to rationalize the evidence.

Keywords: Immigration, labor shortages, search and matching models.

JEL classification: E24, E32, J63, J64, F22.

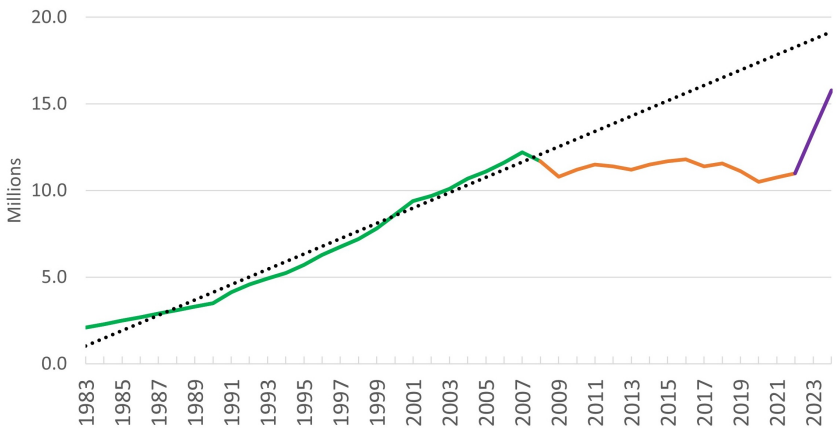
*We thank Andres Blanco, Andrei Zlate, and conference participants at SED 2025, and WESEAMS 2025 for helpful comments. Nick Croteau provided excellent research assistance. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Federal Reserve Bank of Atlanta or the Federal Reserve System. The usual disclaimer applies.

1 Introduction

Since 2019, all employment growth in the U.S. has stemmed from increased employment of foreign-born workers, while employment among native-born individuals has remained at pre-pandemic levels. During this period, employment of foreign-born individuals increased by 12 percent, accounting for the entire 3 percent total employment growth in the United States.

Immigration has shown significant volatility since the mid-2000s, primarily linked to large fluctuations in unregulated inflows, particularly among low-skilled workers entering through the U.S.-Mexico border.[1] Figure 1 illustrates the evolution of unregulated immigration to the United States. After growing rapidly from the 1980s onward, the growth of unregulated workers leveled off during the Great Recession of 2008. The subsequent plateau until 2022 (orange line) contributed to a steady buildup of labor shortages in low-skilled occupations while output recovered from the Great Recession, yet the stock of undocumented immigrants remained below trend.[2] As discussed below, these labor shortages evolved into severe bottlenecks following the Covid-19 pandemic, and the sharp rebound in unregulated immigration between 2021 and 2024 (purple line) helped alleviate some of these shortages.[3]

Figure 1: Stock of Undocumented Immigrants in the United States



Notes: The figure shows estimates of the stock of undocumented immigrants in the United States (in millions, at an annual frequency), obtained from PEW Research (1983-2008, in green); the U.S. Department of Homeland Security and U.S. Citizenship and Immigration Services (2009-2022, in orange); and the Congressional Budget Office (2023-2024, in purple), along with the linear pre-2007 trend (dotted black line).

[1] Unregulated immigration includes undocumented (unauthorized) workers, refugees, and individuals granted Temporary Protected Status (TPS).

[2] See Cohen and dup Shampine (2022) and Mandelman et al. (2024) for a description of the evidence.

[3] According to the CBO, the cumulative net inflow reached approximately 4.9 million individuals—an increase of 45 percent from 2019 levels.

In light of these labor market dynamics, we address the following research questions. How do major changes in immigration affect labor market dynamics? To what extent are they associated with labor shortages, vacancy postings, and wage pressures? Finally, can the textbook search and matching model of the labor market account for these observed patterns? These are important questions because the extensive literature on cyclical labor market dynamics has largely overlooked fluctuations in *labor supply*. Traditionally, shifts in labor supply are associated with slow-moving demographic and social trends—factors considered secondary to business cycle fluctuations that are the focus of our analysis.

We document three new empirical facts that reveal the cyclical interplay between immigration, labor shortages, wage growth, and vacancy postings during the high-immigration period of 2020-2024. We define a sectoral labor shortage as a cyclical decline in a sector's employment share accompanied by strong vacancy posting—a sign of bottlenecks arising from low employment alongside elevated job vacancies in the effort to hire workers. With this measurement, we establish three new facts. Fact 1 shows that sectoral labor shortages predict vacancy growth. We interpret this as elevated labor demand in industries with unusually low employment shares relative to long-term trends. Fact 2 consistently shows that labor shortages also predict wage growth in the affected industries. Most importantly, Fact 3 reveals a negative correlation between immigration inflows and vacancy growth, suggesting that immigration-driven job creation may have helped resolve labor shortages.

We show that the textbook Diamond-Mortensen-Pissarides (DMP) search and matching model—the workhorse model used to study the cyclical dynamics of labor markets—cannot rationalize the observed labor market dynamics in response to an immigration shock, as we discuss in detail below. To reconcile our empirical findings, we extend the standard DMP model with two key features: (i) a Leontief production technology, which creates labor market shortages by making high- and low-skill workers complementary in production, and (ii) a segmented labor supply, where immigrants provide low-skill labor and natives supply high-skill labor. This segmentation aligns with empirical trends over the past four decades, wherein an increasingly educated native workforce has concentrated in high-skill occupations (e.g., professionals, technicians), while immigrants have predominantly filled low-skill service jobs (e.g., caregiving, hospitality).

The key mechanism in our model is the link between labor shortages and job value. As low-

skilled workers become scarcer, their role in production becomes more critical, which *increases* the value of a low-skill job. This, in turn, gives firms a stronger incentive to post vacancies in the low-skill sector. Immigration alleviates these shortages by expanding the pool of low-skill labor, which *reduces* the value of a job and the equilibrium tightness ratio and wage—consistent with our empirical findings.

In contrast, the textbook DMP model assumes that the value of a job is independent of labor shortages, and it is instead determined by labor demand factors like labor productivity and the discount factor. In the textbook model, a surge in immigration increases "search unemployment" as newly arrived workers enter the labor force and search for jobs. The model predicts that a rise in unemployment is matched one-for-one by an increase in vacancies, as firms face lower hiring costs when unemployed workers are abundant. Consequently, the textbook model predicts that key variables like labor market tightness (the vacancy-unemployment ratio) and wages for low-skilled workers remain unchanged in response to immigration inflows—a prediction at odds with the evidence.

In Appendix D, we show that our model's predictions align remarkably well with the observed outward shift in the Beveridge curve after 2020. The textbook model, by contrast, predicts a counterfactual upward-sloping Beveridge curve in this scenario.

Related literature. Our study relates to several strands of literature. First, on the macroeconomic effects of immigration, Hanson et al. (2017) documents the post-Great Recession slowdown, a trend linked to subsequent labor shortages by Cohen and dup Shampine (2022) and Mandelman et al. (2024). More recently, Cheremukhin et al. (2024) analyzes the post-pandemic immigration surge through a frictionless, Walrasian model. Our contribution is to document novel stylized facts and to develop a new theoretical framework, based on the textbook search and matching model, that explains the cyclical interplay between immigration fluctuations and labor shortages.

Second, we connect to studies with search and matching models that incorporate immigration. Chassamboulli and Palivos (2014) shows immigration boosts vacancy posting, a finding supported empirically by Battisti et al. (2018). Hauser and Seneca (2022) and Platonov (2023) explore related frictions in the contexts of monetary policy and post-pandemic firm entry.[4]

[4]Fernández-Villaverde et al. (2021, 2024a,b) emphasize the role of search complementarities and production

Our contribution to this strand of research is to introduce labor market segmentation and complementarities, capturing a key mechanism through which immigration alleviates bottlenecks in low-skilled sectors.

Finally, our work builds on the literature establishing economic shortages as a key driver of business cycles, as shown by Michaillat and Saez (2015) and Ghassibe and Zanetti (2022). The study by Michaillat (2024) is perhaps the closest to our analysis. It resolves the DMP model's inability to generate migration-induced unemployment by introducing a concave production function, creating "job rationing" relevant for depressed economies. Our focus is orthogonal: we analyze the different 2020-2024 period of labor shortages, where immigration helps ease, rather than intensify, labor market pressures.

The remainder of the paper is structured as follows. Section 2 presents the empirical evidence. Section 3 develops a modified DMP model to replicate the empirical regularities. Section 4 concludes.

2 Empirical evidence

In this section, we develop our measure of labor shortages based on the deviation of the sectoral employment shares from long-run trends and present the three key empirical facts linking immigration to labor market dynamics for the period 2020-2025. We show that industries with labor shortages exhibit higher vacancy growth (Fact 1) and higher wage growth (Fact 2). In turn, vacancies are filled more rapidly in sectors that attract immigrants (Fact 3). These facts demonstrate significant links between immigration, labor shortages, vacancies, and wages, and highlight the equilibrating role of immigration in alleviating labor shortages and wage pressures.

We conceptualize sectoral labor shortages in labor markets as bottlenecks arising from low sectoral employment amid high vacancy posting. To quantify this idea, we define the sectoral labor shortage as a cyclical decline in a sector's employment share accompanied by robust vacancy posting.

Sectoral employment share and deviation from the trend. We measure the sectoral employment share (s_t^i) as the ratio of sectoral employment (N_t^i) to total employment (N_t); i.e., $s_t^i = N_t^i/N_t$, where $\sum_i s_t^i = 1$ for each time t. We estimate the long-run trends in the

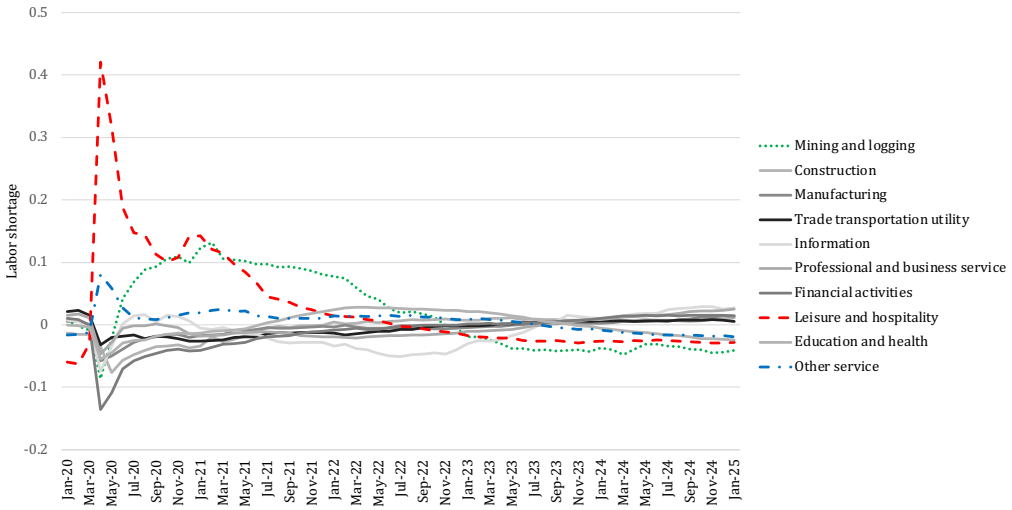
synergies.

logarithm of employment shares using the HP-filter and we interpret the trend as representing the slow-moving, structural transformation in sectoral employment shares of the U.S. economy. We use the log-deviations of the labor share from the trend as representing the cyclical movements away from the long-run structure and denote them by $\widehat{s}_t^i$.

We interpret a negative $\widehat{s}_t^i$ (i.e., an employment share below trend) alongside high vacancy postings as evidence of sectoral labor shortages because it indicates a scarcity of labor input in the sector by leading to a decrease in sectoral employment share despite firms' efforts to expand employment by posting vacancies. For our interpretation to hold, it is essential to observe a negative correlation between $\widehat{s}_t^i$ and vacancies posting, symptomatic of below trend employment share and simultaneous above vacancy postings. A positive correlation would instead suggest a different dynamic, such as a fall in labor demand due to declining labor productivity, where a falling employment share is accompanied by reduced hiring. As Fact 1 will demonstrate, we find the negative correlation, validating our interpretation.

Measure of sectoral labor shortages from cyclical employment shares. We denote labor shortage in sector i at time t with Δ_t^i, and consistent with our interpretation, we set it equal to the inverse of the deviation of employment shares from their long-term trends; i.e., $\Delta_t^i = -\widehat{s}_t^i$. Thus, a positive labor shortage ($\Delta_t^i > 0$) indicates a temporary shortage of workers the sector i.[5]

Figure 2: Sectoral labor shortages (2020-2025) using $\Delta_t^i = -\widehat{s}_t^i$



Notes: This figure illustrates sectoral labor shortages across one-digit NAICS industries from 2020 to 2025. See the main text for details.

[5] Michaillat and Saez (2022) provide a theoretical rationale that the economy is efficient at the Beveridge threshold.

Figure 2 illustrates labor shortages, measured by $\Delta_t^i = -\widehat{s}_t^i$, across one-digit NAICS private industries from 2020 to 2025. It shows that the Leisure and Hospitality sector (red dashed line) experienced a sharp increase in labor shortages in Q1 2020. This sector accounts for 11 percent of total U.S. employment and serves as the largest employer of low-skilled immigrants (Chapuis et al., 2023). Most representative jobs in this sector include restaurant workers, maids, housekeepers, and cleaners. While the Leisure and Hospitality sector contains a sizable share of "high-contact" jobs with high exposure to the Covid-19 pandemic, other industries with comparable exposure—such as Retail, Transportation, and Healthcare Assistance—did not experience similarly severe shortages. This divergence suggests that the sector's acute labor shortfalls were driven not entirely by health risks, but by a specific scarcity of its core workforce.

Importantly for our analysis, the U.S. largely reopened from the pandemic by the end of 2020, yet sectoral labor shortages persisted well beyond 2021. The increase in immigration starting around 2021 significantly reduced the severity of labor shortages in the Leisure and Hospitality sector. Immigrants arriving between 2022 and 2024 accounted for 6.5 percent of the sector's total employment, a period during which job openings in the sector decreased by 55 percent. Most other sectors (gray lines of varying shades), except for Mining and Other Services, experienced either a decline or stability in their labor shortages. By the end of 2024, labor shortages were almost entirely resolved across all sectors.

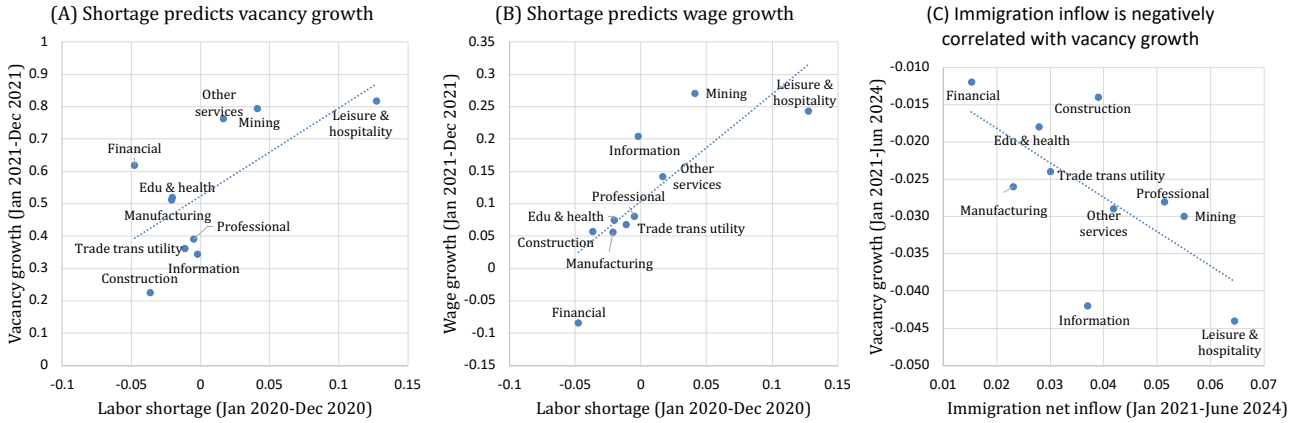
Since our interest is on the direct relationship between immigration with vacancy posting and wages during elevated labor shortages, we take 2020 as a reference year of an unprecedented increase in labor shortages, as evidenced by Figure 2. We calculate the average labor shortage across sectors for the year 2020 as: $\overline{\Delta}^i = \sum_{t\in[Jan20,Dec20]} \Delta_t^i/12$, and examine the relationship between $\overline{\Delta}^i$ and the subsequent growth in vacancies and wages during 2021 (January to December 2021). This approach allows us to assess whether pre-existing labor shortages had significant predictive power for subsequent wage and vacancy dynamics.

Fact 1: Labor shortage predicts vacancy growth. Panel (A) in Figure 3 shows labor shortages in 2020 ($\overline{\Delta}^i$, x-axis) and the growth rate of vacancy posting in 2021 (y-axis). The significant positive correlation (at the 5% level) validates our measure of labor shortages: sectors with the most pronounced shortages—notably Leisure and Hospitality, Mining, and Other Services—are precisely those that experienced the strongest subsequent vacancy growth,

consistent with our interpretation of sectoral labor shortages from the reduction in the cyclical employment shares amid robust vacancy posting in those industries.

Regression results, also including alternative forecasting horizons reported in Appendix A.2, further reveal that labor shortages exhibit significant predictive power for future vacancy growth extending up to twelve months ahead. This significant predictive relationship validates our measurement of labor shortages and indicates that they are a persistent and important driver of labor demand.

Figure 3: Labor shortages, vacancy and wage growth rates, and immigration



Notes: The figure presents scatter plots illustrating the relationship between labor shortages and subsequent vacancy growth (Panel A), as well as future wage growth (Panel B), across one-digit NAICS private industries. Panel (C) displays the correlation between net immigration inflows and vacancy growth.

Fact 2: Labor shortage predicts wage growth. Panel (B) in Figure 3 studies the relationship between labor shortages (x-axis) in 2020 and the growth rate of wages in 2021 (y-axis). The result shows a strong positive correlation, significant at the 1% level, indicating that sectors with more severe labor shortages subsequently experienced higher wage growth. This is consistent with our earlier conjecture that labor shortages imply a surge in labor demand and demonstrates that labor shortages are significantly associated with positive wage growth. The Leisure and Hospitality sector, which had the most pronounced shortage, recorded the highest subsequent wage growth.

Table A.2 in Appendix A.3 reports regression results studying the link between sector-specific wage growth to labor shortages across several sample windows. The estimates reveal that shortages in 2020 were a strong and persistent predictor of wage increases in subsequent years.

Fact 3: Net immigration is negatively correlated with vacancy growth. Finally, we show that immigration acts as a strong equilibrating force, relieving sectoral labor shortages. Panel (C) of Figure 3 reveals a negative correlation (significant at 5% level) between the growth in the foreign-born employment share and sectoral vacancy growth from December 2021 to July 2024. This indicates that immigration inflows systematically reduce vacancy posting by mitigating the underlying labor shortages.[6]

Under the lens of the canonical search and matching DMP model, Fact 3 presents a puzzle for the model. In that framework, an immigration-driven increase in labor supply should incentivize firms to post more vacancies to hire newly available workers and *increase* vacancy postings. However, the main idea of our analysis is that vacancies also respond to labor shortages, and immigration acts as an equilibrating force that lowers both shortages and the resulting labor demand and vacancy postings.

3 A simple model with labor shortages

In this section, we develop a simple model that accounts for the positive relationship between labor shortages, vacancy posting and wages, while allowing immigration to ease those shortages by filling job openings, consistent with the evidence in Section 2.

Our framework builds on the long-term trend of occupational sorting observed over the past four decades: Natives fill high-skilled occupations, while immigrants have mainly taken low-skilled service jobs, such as food preparation, cleaning, and child/elderly care.[7] We formalize the idea that these immigrant-provided services constitute *essential needs* that high-skilled household members must have met in order to join the labor force. The unavailability or high cost of these services can force household members to reduce their work hours or exit the labor market altogether.[8] To capture this important idea in the textbook DMP model, we introduce

[6]Our analysis is consistent in the approach and and results in Cohen (2024) who also show that industries experiencing higher immigrant inflows after January 2021 also saw a more rapid decline in job vacancies. This increase in foreign-born employment contributed to a 4.4% reduction in the vacancy rate in the sector, which itself represents 11% of total U.S. employment.

[7]The foreign-born alone accounts for most of the employment growth in these occupations over the past forty years (Mandelman and Zlate, 2022).

[8]For instance, if childcare and other essential household services are unavailable or prohibitively expensive due to acute labor shortages, a household member would likely have to reduce their work hours or leave the labor force.

two complementary worker types—high-skill (native) and low-skill (immigrant)—through a Leontief production function. This parsimonious extension generates dynamics consistent with Facts 1-3, which the textbook DMP model cannot explain.

3.1 Baseline environment

Time is discrete, $t = 1, 2, \ldots$. The economy has two sectors. One sector produces output by hiring native, high-skilled N_t^H workers. The other sector hires foreign-born, low-skilled N_t^L workers. The output of each sector is a linear production function with respect to labor:

$$Y_t^H = z_t N^H, \quad Y_t^L = z_t N_t^L,$$

where z_t is the labor productivity equal across sectors. Importantly, the two sectors are complementary in the production of final output, which is manufactured according to the Leontief production function:

$$Y_t = \min\left(Y_t^H, Y_t^L\right) = z_t \min\left(N^H, N_t^L\right). \tag{1}$$

Consequently, a labor shortage occurs when there is an imbalance (gap) between employment in the two sectors. A labor shortage in the low-skilled sector, forces members of the high-skilled sector to leave the labor force (or refrain from entering it) in order to meet some of the essential needs mentioned. For simplicity, we assume that job creation and separation are always constant and equal to each other in the high-skilled sector, implying that high-skilled employment is fixed: $N_t^H \equiv N^H$. Instead, labor shortages for low-skilled labor can arise due to immigration restrictions, i.e., $N_t^L \leq N^H$. By assumption, workers of different skills cannot move across sectors.

We define labor shortage as the gap between labor in the high-skilled and low-skilled sectors, formally equal to:

$$\Delta_t = N^H - N_t^L, \tag{2}$$

This reflects the unmet demand for low-skilled immigrant labor, which would prevent high-skilled natives to participate fully in the labor market.[9] By substituting equation (2) into equation (1),

[9]In the steady state without labor shortage, employment of the low-skill workers satisfies $N^L = N^H$, where

we derive the aggregate production function:

$$Y_t = z_t \left(N^H - \Delta_t \right), \tag{3}$$

which highlights that output diminishes as the labor shortage intensifies.

3.2 Search and matching in the low-skilled sector

Firms post vacancies in the low-skilled sector, while the high-skilled sector remains passive with no recruitment activities. The measure of new matches in the low-skilled sector is determined by the standard Cobb-Douglas matching function: $m_t = \phi v_t^{\alpha} u_t^{1-\alpha}$, where ϕ, v_t, and u_t are the matching efficiency, and measure of vacancy and unemployment, respectively. The job finding rate, $\mu_t(\theta_t)$, and vacancy filling rate, $f_t(\theta_t)$, are equal to:

$$\mu_t(\theta_t) = \phi \theta_t^{\alpha} \text{ and } f_t(\theta_t) = \phi \theta_t^{\alpha - 1}, \tag{4}$$

respectively, where $\theta_t = v_t / u_t$ is the labor market tightness ratio, and $\mu_t(\theta_t)' > 0$ and $f_t(\theta_t)' < 0$.

3.3 Law of motion for low-skilled employment and labor shortages

The employment in the low-skilled sector evolves according to:

$$N_t^L = \max\{(1-\delta) N_{t-1}^L + m_t, N^H\}, \tag{5}$$

where current employment at time t results from employment from the previous period $t-1$ net of job separation at a rate of δ, plus job creation in the current period. Due to technological complementarities arising from the Leontief technology in equation (1), employment in the low-skill sector cannot exceed employment in the high-skill sector.

By subtracting N^H from both sides of Equation (5), the labor shortages are equal to:

$$\Delta_t = \min\{\Delta_{t-1} - (m_t - \delta N_{t-1}^L), 0\}, \tag{6}$$

N^L is the steady state value of N_t^L. Thus, equation (2) can be derived as: $\Delta_t = -(N_t^L - N^L) \propto -(\frac{N_t^L - N^L}{N^L + N^H}) \approx -(\frac{N_t^L}{N_t^L + N^H} - \frac{N^L}{N^L + N^H})$, which mirrors the empirical measure of labor shortage: the inverse of the deviation of employment share from its steady state level.

where $m_t - \delta N_{t-1}^L$ is the net job creation in the low-skill sector. The law of motion of labor shortages can be partitioned into two cases, depending on whether the number of new matches is sufficiently high to resolve labor shortages.

Case 1 (unresolved labor shortages): $m_t < \Delta_{t-1} + \delta N_t^L$**.** In this case, the creation of new low-skilled jobs net of job separation is insufficient to resolve labor shortages. Thus, the law of motion of labor shortages is equal to:

$$\Delta_t = \Delta_{t-1} - m_t + \delta N_{t-1}^L. \tag{7}$$

Case 2 (resolved labor shortages): $m_t \geq \Delta_{t-1} + \delta N_t^L$**.** In this case, the labor shortages are resolved, implying that $\Delta_{t+j} = 0$ for $j \geq 0$. Without labor shortages, the low-skill sector satisfies the stationary steady state with $N_{t+j}^L = N^H$ and $\Delta_{t+j} = 0$ for $j \geq 0$.

In accordance with our assumption $N_t^L \leq N^H$, any "excess" match that causes the number of low-skilled workers to exceed the number of high-skilled workers—measured by $m_t - \delta N_{t-1}^L - \Delta_{t-1}$—is dissolved without production. This assumption is central to the role of labor shortages for the free-entry condition, as we describe in the next section.

3.4 Free-entry condition in the low-skilled sector

The free-entry condition for vacancy posting in the low-skilled sector is:

$$\frac{\kappa}{f_t(\theta_t)} = \beta p_t E_t \left(J_{t+1} \right), \tag{8}$$

which equates the expected costs (left-hand side) to the expected benefits of matching (right-hand side). The expected costs involve the cost of posting a vacancy κ divided by the rate of vacancy filling $f_t(\theta_t)$, as in the workhorse DMP model. The expected benefits depend on the firm's expected value of a filled vacancy, $E_t \left(J_{t+1} \right)$, discounted at the rate β (since it takes one period for the match to contribute to production), as in the standard DMP model. However, different from the canonical DMP model, in our setup the expected benefits are also discounted by the probability p_t that the new match will not generate a number of low-skilled workers in excess of the high-skilled workers, in accordance with the assumption $N_t^L \leq N^H$, as otherwise the match is dissolved (for this reason, we refer to p_t as the *match survival rate*). The match survival

rate decreases when the new matches are close to becoming in excess of the full resolution of labor shortages (i.e., $m_t > \delta N_{t-1}^L - \Delta_{t-1}$), simultaneously reducing the expected value of the match and the firm's incentives to post vacancies. To capture these intuitive forces, we define the match survival rate (p_t) as follows:

$$p_t = \begin{cases} 1 & \text{if } m_t < \widetilde{\Delta}_{t-1} \\ \frac{\widetilde{\Delta}_{t-1}}{m_t} & \text{if } m_t \geq \widetilde{\Delta}_{t-1} \end{cases}, \tag{9}$$

where $\widetilde{\Delta}_{t-1} \equiv \Delta_{t-1} + \delta N_{t-1}^L$ is the number of workers required to resolve labor shortage. Equation (9) implies that if the number of new matches is below the number of workers needed to resolve labor shortages (i.e., $m_t < \widetilde{\Delta}_{t-1}$), the match survival rate (p_t) is equal to one, as in the standard DMP model. Otherwise, if new matches are in excess to the full resolution of labor shortages (i.e., $m_t \geq \widetilde{\Delta}_{t-1}$), the probability is below one and it decreases with the number of excess matches.

The match survival rate captures the effect of labor shortage on the value of vacancy posting, which is a central component in our model to replicate the observed positive correlation between labor shortages with vacancies and wage growth (Facts 1 and 2) and the negative relationship between immigration and vacancy growth (Fact 3). When the match survival rate is equal to one ($p_t = 1$), Equation (8) nests the free-entry condition of the standard DMP model, and vacancy posting perfectly co-moves with immigration, since immigrants increase the availability of unemployed low-skill workers, reducing hiring costs and consequently fostering the growth of vacancy posting, leaving the equilibrium tightness ratio unchanged. In our model, instead, the match survival rate declines when new matches resolve the labor shortages, which reduce the expected benefits for firms of forming a match, such that vacancy posting declines with the resolution of shortages despite the increase in unemployment for low-skilled jobs resulting from immigration.

Our model introduces a direct link between labor shortages and vacancy posting associated with the resolution of the shortages that is absent in the standard DMP model. To highlight the important consequences for the link between vacancies and labor shortages, we rewrite the free-entry condition in Equation (8) by substituting Equations (4) and (9), and using the

definition of labor market tightness $v_t = \theta_t u_t$, which yields:

$$v_t = \begin{cases} \left[\frac{\phi\beta E_t(J_{t+1})}{\kappa}\right]^{\frac{1}{1-\alpha}} u_t & \text{if } m_t < \widetilde{\Delta}_{t-1} \\ \frac{\beta E_t(J_{t+1})\widetilde{\Delta}_{t-1}}{\kappa} & \text{if } m_t \geq \widetilde{\Delta}_{t-1} \end{cases}. \tag{10}$$

Equation (10) shows that when new hiring is below the full resolution of labor shortages ($m_t < \widetilde{\Delta}_{t-1}$), the number of vacancy posting v_t is proportional to unemployment u_t, as in the standard DMP model. In such a case, an exogenous increase in unemployment arising from an increase in immigration stimulates vacancy posting such that vacancy and unemployment perfectly comove. However, when new hiring resolves labor shortages $m_t \geq \widetilde{\Delta}_{t-1}$ and some matches are excessive, the number of vacancy postings is proportional to labor shortages. Thus, a reduction in the labor shortage generates a decrease in vacancies. This mechanism is consistent with the strong negative comovement between vacancies and immigration during periods of elevated labor shortages (Fact 3), a puzzling empirical pattern if interpreted with the positive comovement between immigration and vacancies in the standard DMP model.[10]

3.5 Unemployment and immigration in the low-skilled sector

The law of unemployment is equal to:

$$u_{t+1} = u_t - p_t m_t + im_t + \delta N_t^L, \tag{11}$$

where unemployment in the next period (u_{t+1}) is determined by the unemployment in the current period (u_t), net of the outflow into employment ($p_t m_t$), plus current immigration (im_t) and job separations (δN_t^L).[11]

At the beginning of each period t, immigration is linked with labor shortages and determined by:

$$im_t = \psi \Delta_t, \tag{12}$$

[10] Note that $m_t = \phi v_t^{\alpha} u_t^{1-\alpha}$. Based on equation (10), the condition $m_t < \widetilde{\Delta}_{t-1}$ is satisfied if $\phi^{\frac{1}{1-\alpha}} \left[\frac{\beta E_t(J_{t+1})}{\kappa}\right]^{\frac{\alpha}{1-\alpha}} < \frac{\widetilde{\Delta}_{t-1}}{u_t}$. Conversely, the condition, $m_t \geq \widetilde{\Delta}_{t-1}$, is satisfied if $\phi^{\frac{1}{1-\alpha}} \left[\frac{\beta E_t(J_{t+1})}{\kappa}\right]^{\frac{\alpha}{1-\alpha}} \geq \frac{\widetilde{\Delta}_{t-1}}{u_t}$.

[11] In line with Michaillat (2024), who provides a realistic framework for modeling immigration in models with search and matching frictions, equation (11) implies that current immigrants (im_t) contribute to unemployment in the subsequent period $t+1$, since they must wait one period before beginning their job search.

where ψ measures the stance of immigration policy, such that $\psi\Delta_t$ dictates how much immigration surges when labor shortages arise.[12]

3.6 Value functions and wage determination

We next define the Bellman equations that determine the value of a filled job for a firm (J_t), an employed worker (W_t), and an unemployed worker (U_t), which establish the total surplus from working that will be shared between workers and firms through the wage.

The value of a filled job is determined by:

$$J_t = z_t - w_t + \beta(1-\delta)E_t\left(J_{t+1}\right), \tag{13}$$

where z_t is output and w_t wages in period t. In the next period $t+1$, if the job survives separation at the rate $1-\delta$ the firm receives the discounted (at the rate β), expected job value.

The value of an employed low-skilled worker is determined by:

$$W_t = w_t + \beta E_t\left[(1-\delta)W_{t+1} + \delta U_{t+1}\right], \tag{14}$$

where the worker receives the wage in the current period t. In the next period $t+1$, the worker expects to receive the value of the job if it survives separation, or the value of being unemployed if the job terminates.

The value of an unemployed low-skilled worker is determined by:

$$U_t = h + \beta\left[p_t\mu_t E_t\left(W_{t+1}\right) + \left(1-p_t\mu_t\right)E_t\left(U_{t+1}\right)\right], \tag{15}$$

where the unemployed worker receives home production h in the current period t. In the next period $t+1$, the worker finds a job with probability $p_t\mu_t$, receiving the expected value $E_t\left(W_{t+1}\right)$; otherwise, the worker remains unemployed and receives the expected value $E_t\left(U_{t+1}\right)$.

The total surplus of a job match is equal to: $TS_t = W_t - U_t + J_t$. During each period t, the wage is set by Nash bargaining that splits the total surplus between firm and worker, and the worker receiving the constant share τ, such that the share of the total surplus accruing to the

[12]The parameter ψ can be interpreted as representing forces like immigration policy and cross-country wage differentials linked with the flow of migration, which are treated as exogenous in our simple model.

worker is equal to $W_t - U_t = \tau TS_t$, while the share of the total surplus accruing to the firm is equal to: $J_t = (1-\tau)\, TS_t$.

We obtain an explicit solution for the total surplus of a job match by combining the Bellman equations (13)-(15) and the wage resulting from Nash bargaining:

$$TS_t = z_t - h + \beta\,(1 - p_t\mu_t\tau - \delta)\, E_t\,(TS_{t+1})\,. \tag{16}$$

Equation (16) shows that the total surplus increases with labor productivity z_t, but decreases with both the job finding rate $\mu_t(\theta_t)$ and the match survival rate determined by the resolution of labor shortages, specified by Equation (9). Intuitively, higher values of $\mu_t(\theta_t)$ or p_t increase the worker's bargaining position due to an increase in the tightness in the labor market that makes hiring more expensive to firms, thereby raising the wage and reducing the value of the firm. If labor shortages are not resolved and therefore $p_t = 1$, Equation (16) nests the standard Bellman equation for the total surplus in the canonical DMP model.

Equilibrium of the system. Equations (7), (10), (11), (12), and (16) determine the equilibrium values of unemployment (u_t), vacancies (v_t), immigration (im_t), labor shortages (Δ_t), and total surplus (TS_t). The wage in the low-skilled sector (w_t) is determined by Equation (13), while output (Y_t) is determined by Equation (3). If labor shortages are fully resolved, the low-skilled sector reaches the *no-shortage steady state*, characterized in Appendix B. Since the system is nonlinear, we resort to numerical simulation to obtain the equilibrium; Appendix C describes the solution method.

3.7 Quantitative analysis

Calibration. We calibrate the model on monthly U.S. data, primarily following Shimer (2005). We set the matching elasticity α to 0.28 and the worker's bargaining share τ to 0.72, which together satisfy the Hosios condition. We normalize the steady-state labor productivity z and vacancy cost κ to 1 and set the flow value of home production h to 0.4. Additionally, we calibrate the discount rate β to the standard value of 0.996.

We calibrate the parameter for the matching efficiency ϕ adopting the strategy in Shimer (2005) and targeting the value for job-finding rate of 0.45 that applies in the absence of labor

shortage (when the system approaches the steady state), implying $\phi = 0.95$.

To study the transition dynamics towards the equilibrium, we need to calibrate the initial levels of unemployment and labor shortage (u_1 and Δ_1, respectively). The unemployment rate surged to 15% in April 2020, compared to 4% in March 2020. The employment share in the Leisure and Hospitality sector recorded a steady increase in the early part of the same sample period, peaking at 10.7% in March 2020 before dropping to 6.7% in April 2020 due to the COVID-19 pandemic (see Figure A.2 in Appendix A.5). We set the beginning period of our simulation to April 2020, and consequently set the initial values at $u_1 = 0.15$ and $\Delta_1 = 1 - 0.067/0.107 = 0.37$.

We set the immigration intensity parameter ψ to 0.23, implying that the cumulative inflow of immigrants along the transition path toward the no-shortage steady state is equal to approximately 50% of the initial labor shortfall, consistent with observed data.[13]

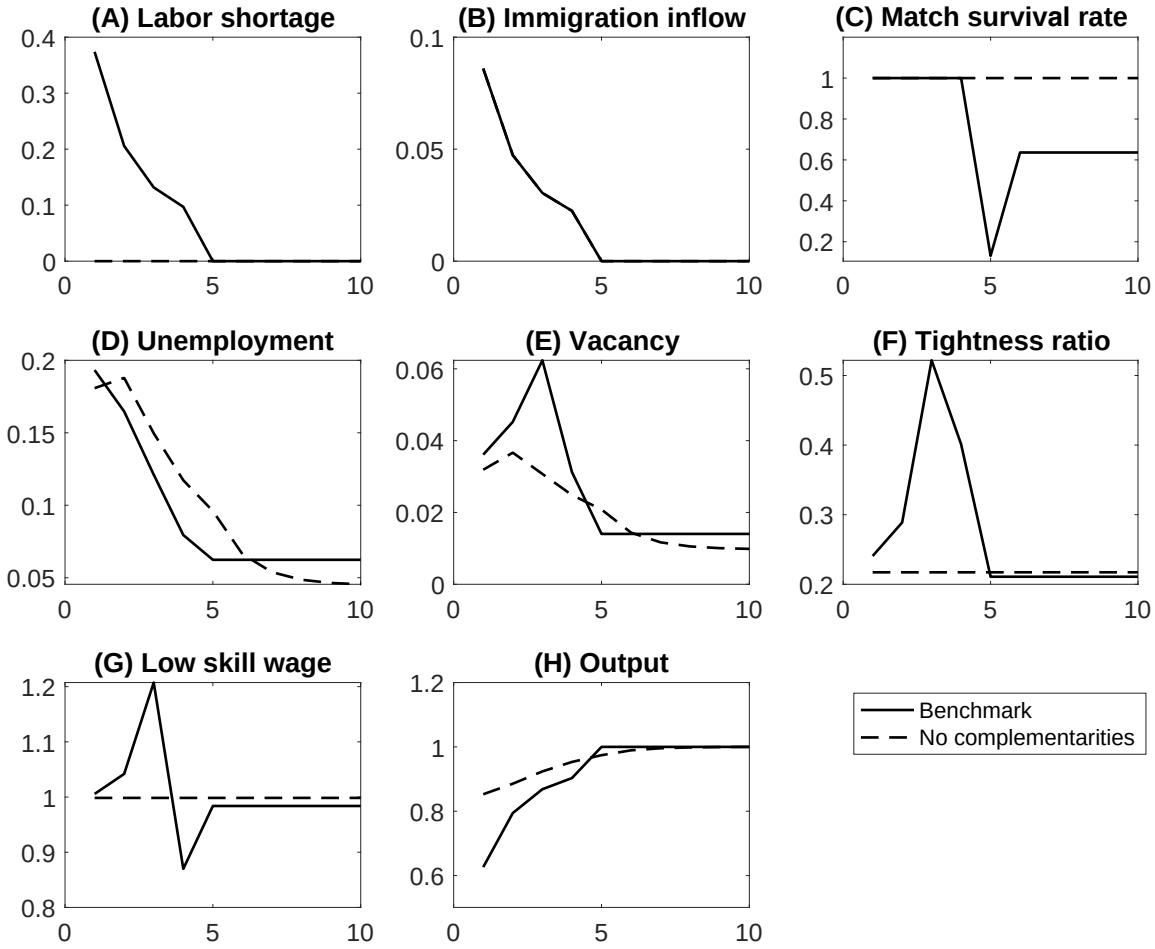
Transition dynamics in the benchmark model. Our calibration implies that the economy begins with exceptionally high unemployment and labor shortages, as observed around March 2020, since $u_1 = 0.15$ and $\Delta_1 = 0.37$. Aside from the initial deviation from the zero-shortage steady state, the system is free of exogenous shocks, and its transitional dynamics evolve endogenously according to the equations in the model, ultimately converging to the no-shortage steady state.

Figure 4 shows the transition dynamics, taking the variables in the system from the initial equilibrium with significant labor shortages to the steady-state equilibrium where labor shortages are resolved. The solid line shows the transition dynamics for the variables in our benchmark model, while the dashed line shows the transition dynamics for a counterfactual version of our model that nests the standard DMP model without labor shortages and complementarities (described below).

The initial surge in labor shortages (Panel A) triggers a rise in immigration inflows (Panel B). The initial shortage of labor implies that the match survival rate is equal to one (Panel C), while also increasing the pool of unemployed low-skilled workers, as it takes one period for new entrants to engage in the job market (Panel D). Firms respond to the labor shortage and the

[13]The initial labor shortage across the Mining, Leisure and Hospitality, and other services sectors is estimated at 9.7 million workers, while the cumulative inflow of irregular immigrants is approximately 4.9 million, representing about 50% of the initial shortage.

Figure 4: Transition dynamics



Notes: The figure shows the transition dynamics for labor shortage (Panel A), low skill immigration inflow (Panel B), match survival rate (Panel C), unemployment (Panel D), vacancy (Panel E), tightness ratio (Panel F), low skill wage (Panel G), and output (Panel H). Solid and dashed lines represent simulations from the benchmark model and from the standard DMP model without labor shortages or complementarities.

large inflow of immigration by posting vacancies on impact (Panel E), and the resulting increase in labor market tightness (Panel F) raises wages slightly in the first period (Panel G). Output expands (Panel H) in response to the increase in the inflows of low-skill workers and the ensuing pick-up in vacancy posting.

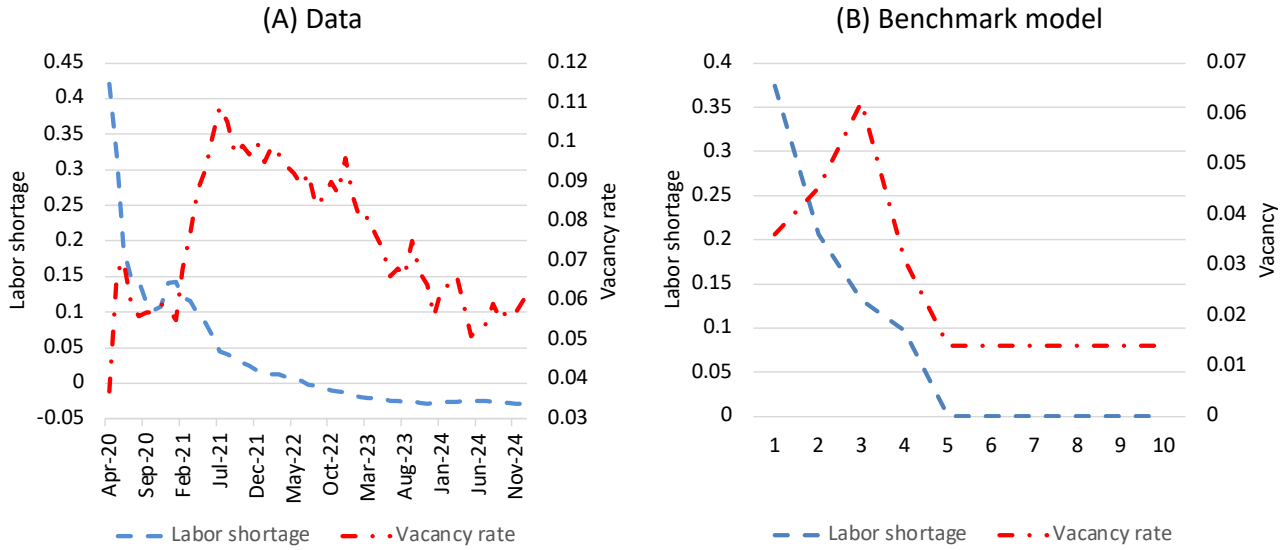
From the second period onward, the economy starts converging to the steady-state-no-shortage equilibrium. The initial increase in vacancy posting decreases labor shortages, thereby curtailing the immigration inflow and decreasing unemployment for low-skilled workers. Labor shortages are resolved in the period 5. The robust vacancy posting significantly slows down in period 3 since as labor shortages approach resolution, the match survival rate drops significantly as less low-skilled workers are needed to alleviate labor shortages, discouraging firms from posting

vacancies, so that vacancy posting remains positive but declines substantially after period 3 to reach the steady-state equilibrium in period 5.

The wage for the low-skilled workers raises until period 3, but it then fall afterwards, consequent to the resolution of labor shortages. Wages increase during the first three periods in response to the rise in labor market tightens, resulting from the growth rate of vacancy posting outpacing unemployment, thereby strengthening the outside option value for unemployed workers that leads the firm to increase the wage. However, wages decline in the fourth period as the labor shortage nears resolution, leading to match dissolution with a positive probability, which in turn reduces total surplus and lowers workers' wages.

Unemployment and vacancies move in opposite directions in the first periods of the transition dynamics as the labor shortage nears resolution, consistent with our empirical evidence in Section 2. Such response is driven by the *endogenous* reduction in the job value with the resolution of labor shortages, which induces the firm to decrease vacancy posting despite the increased unemployment of low-skilled workers. Central to our results, as we will show below, these equilibrium forces are absent in the standard DMP model that abstracts from labor shortages and complementarities. Output steadily increases until reaching the higher steady-state level associated with the permanent resolution of labor shortages.

Figure 5: Labor shortage and vacancy in Leisure & hospitality sector



Notes: This figure compares the joint dynamics of labor shortages and vacancy postings as observed in the data (Panel A) and as generated by the benchmark model (Panel B).

Central to the analysis, our stylized model closely aligns with the observed labor market

dynamics, as documented in Facts 1-3 of Section 2. To facilitate comparison between the data and our model, Figure 5 shows the evolution of labor shortages and the vacancy rate for the Leisure and Hospitality sector in the data from April 2020 through December 2024 (Panel A) and in simulations from our benchmark model (Panel B). Consistent with the dynamics in the data, our model replicates the steady decline of labor shortages and the initial surge in vacancy posting followed by the gradual decline.

Counterfactual analysis with no complementarity. In this final part of the analysis, we focus on the transition dynamics in the standard DMP model, obtained as a special case of our model where the low-skilled and high-skilled sectors are substitutable and there are no labor shortages.

Formally, we assume that final output is determined by the linear production function $Y_t = z_t(N_t^L + N^H)/2$. Since the survival rate of new matches is no longer bounded by labor shortage, it yields $p_t = 1$, and equations defining labor market tightness (obtained by using $\theta_t = v_t/u_t$ in equation 10) and the total surplus (the corresponding equation to 16) become:

$$\theta_t = \left[\frac{\phi\beta(1-\tau)E_t(TS_{t+1})}{\kappa}\right]^{\frac{1}{1-\alpha}} \tag{17}$$

and

$$TS_t = z_t - h + \beta\,(1-\delta)\,E_t\,(TS_{t+1})\,, \tag{18}$$

respectively. Since the simulation is free of exogenous shocks, $z_t = 1$ for all periods t. It is straightforward to verify from equations (17) and (18) that θ_t and TS_t are constants and *independent* from the levels of unemployment and immigration. This is a standard property of the canonical DMP model: labor market tightness and job value depend uniquely on labor productivity in equilibrium.

To make the projections of our benchmark model comparable with those of the nested DMP model, we assume that immigration to the low-skilled sector follows the same path as in the benchmark model, such that:

$$u_{t+1} = (1-\mu_t)u_t + \delta N_t^L + i\bar{m}_t, \tag{19}$$

where $i\bar{m}_t$ is the immigration level determined by our benchmark model that serves as the exogenous labor supply shock in the nested DMP model. The dashed line in Figure 4 shows the transition dynamics of the variables in the nested DMP model. By construction, in the nested DMP model there are no labor shortages, and immigration of low-skilled workers is the same as in the benchmark model. In the canonical model, volatile changes in labor supply have zero impact in labor market tightness and wages. The responses of unemployment and vacancies are perfectly proportional to each others, generating a strong positive correlation between these variables. Wages in the low-skilled sector remain constant in the nested DMP model, as they are governed by the labor market tightness ratio, which itself remains unchanged with the proportional increase in vacancies and unemployment during the transition dynamics. Finally, output converges to the unitary value of productivity, while employment in the low-skilled sector reaches the steady state.

4 Conclusion

Since 2019, labor immigration has been the main driver of U.S. labor force growth. We show three new empirical findings that highlight the cyclical interplay between immigration, labor shortages, wage growth, and job openings during the high-immigration period from 2020 to 2024. The acute labor shortages and wage pressures that emerged in 2020 were concentrated in sectors reliant on low-skilled immigrant labor. The subsequent immigration surge served as a strong equilibrating force, easing labor shortages and decreasing both vacancy postings and wage growth.

The textbook search and matching model of the labor market yields counterfactual predictions in this context: immigration-driven increases in labor supply are fully offset by a proportional rise in job vacancies, as the abundance of workers reduces hiring costs, leaving labor market tightness and wages unchanged. To reconcile theory with evidence, we extend the textbook model with skill segmentation (natives in high-skill work, immigrants in low-skill services) and Leontief complementarity between the two groups. This complementarity makes low-skill workers essential for production. A shortage of these workers creates a bottleneck, increasing their job value and prompting firms to post more vacancies and raise wages. Immigration, by expanding this essential labor supply, directly alleviates the bottleneck.

Our research highlights that immigration is not a slow-moving phenomenon tied to demographic and social trends, but rather a powerful cyclical source of labor supply and an equilibrating mechanism that helps resolve labor shortages. The interplay between immigration, sectoral shortages, and skill complementarities is a key mechanism for labor market stabilization. Future research should integrate these distinct forces into business cycle models that account for cyclical changes in labor supply. Our framework could also be extended to link immigration to inflation. We plan to pursue these extensions in future research.

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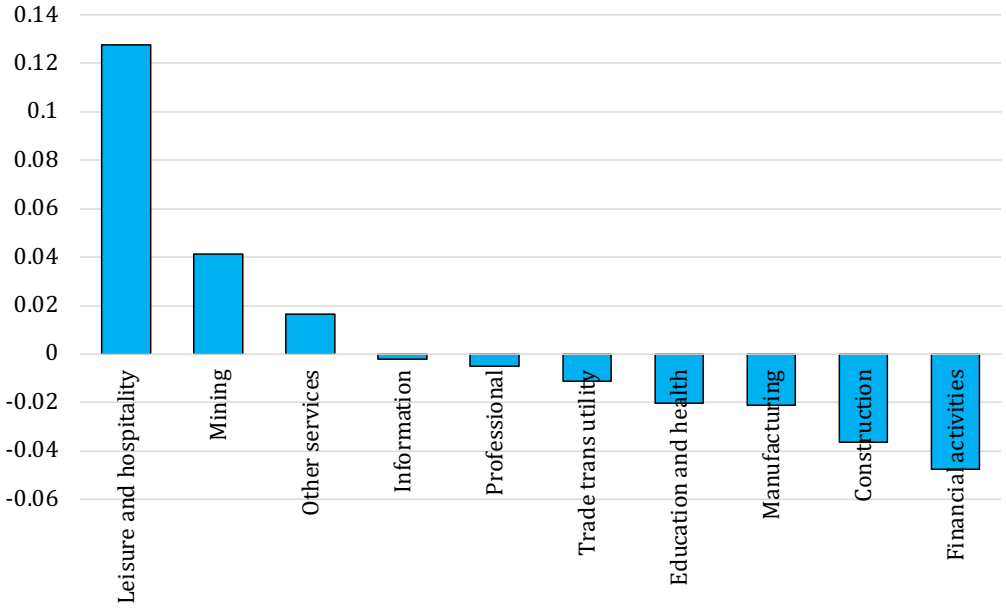
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Online Appendix

A Additional Figures and Tables

A.1 Sectoral labor shortages in 2020

Figure A.1: Sectoral labor shortages in 2020



Notes: Labor shortages using $\Delta_t^i = -\widehat{s}_t^i$ obtained from one-digit NAICS private industries for the period 2020-2025.

Our core hypothesis is that labor shortages in specific sectors prior to the 2022 high-inflation episode partially explain the sharp rise in vacancies and wages in those sectors. To quantify these shortages, we calculate the average labor shortage for the year 2020 as: $\overline{\Delta}^i = \sum_{t\in[Jan20,Dec20]} \Delta_t^i/12$. Figure A.1 illustrates the average sectoral labor shortages in 2020. In particular, the sectors with the most notable shortages during this period are Leisure and Hospitality, Mining, and Other Services. As we will show, these sectors have had the highest vacancy rates and wage increases since 2020.

A.2 Labor shortages and vacancy growth

To formally investigate the dynamic relationship between labor shortages and vacancy growth across industries, we estimate the following predictive regression:

$$\Delta v^i_{t+k} = \alpha + \beta \Delta^i_t + \gamma^i + \chi_t + \epsilon^i_t, \tag{A-1}$$

where Δv^i_{t+k} represents the rate of change in sector i's vacancy rate from a year ago in period $t+k$, and Δ^i_t denotes sector i's labor shortage in period t. γ^i and χ_t denote the sector and time fixed effects, respectively. Data is monthly from January 2020 to December 2024.

Table A.1 presents the estimation results for $k = 0$ (current period), 1 (one month ahead), 6 (six months ahead), 12 (one year ahead), and 18 (one and a half years ahead). The findings show that labor shortages are positively linked to vacancy growth during the same period and are strong predictors of vacancy growth in the following periods up to one year ahead. For instance, a 1% increase in labor shortages (reflected as a 1% decline in the employment share) relative to the long-term trend predicts a 1.71% rise in the vacancy growth rate in the following year, which is economically significant.

Table A.1: Labor shortages and vacancy growth

	(1)	(2)	(3)	(4)	(5)
Dependent variable			Vacancy growth (t+k)		
k	0	1	6	12	18
Shortage (t)	1.28***	1.71***	1.62***	1.27***	0.17
	(0.27)	(0.27)	(0.28)	(0.31)	(0.30)
Industry FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.64	0.66	0.65	0.66	0.51
Observations	600	590	540	480	420

Notes: *p<0.10, **p<0.05, ***p<0.01

To formally analyze the dynamic relationship between labor shortages and vacancy growth across industries, using monthly wage growth data from January 2021 to December 2024, we estimate the following predictive regression:

$$\Delta w^i_t = \alpha + \beta \overline{\Delta}^i + \gamma^i + \epsilon^i_t, \tag{A-2}$$

where Δw_t^i represents the nominal wage growth rate for sector i compared to a year earlier, while $\overline{\Delta}^i$ denotes sector i's average labor shortage in 2020-a period marked by severe labor shortages that preceded the subsequent surge in inflation. It is important to note that the average labor shortage $\overline{\Delta}^i$ is used as the independent variable instead of the monthly labor shortage Δ_t^i because the dynamic relationship between wage growth and Δ_t^i is unstable. Due to staggered wage-setting mechanisms, wage growth does not consistently correlate with vacancy rates or labor shortages in the short term run.[14] Therefore, we examine how the average labor shortage in 2020 forecasts wage growth during periods of high inflation. χ_t represents the time fixed effects. Sector fixed effects are excluded from the regression because the key independent variable, $\overline{\Delta}^i$, remains constant over time.

A.3 Labor shortages and wage growth

Table A.2 shows the estimated results for wage growth across three different sample periods: January 2021-December 2021, which is the year after the 2020 base period as shown in Figure 3; January 2021-June 2022, capturing the period of increased inflation; and January 2021-December 2024, covering both the inflation spike and the cooling phase that followed.

The findings indicate that labor shortages in 2020 were a strong predictor of wage growth in later periods, with the most notable effects seen during the high-inflation period from January 2021 to June 2022. Specifically, a 1% increase in average labor shortages-equivalent to a 1% decline in the average employment share compared to the long-term trend-is linked to a 0.16% rise in the wage growth rate.

Table A.2: Labor shortages and wage growth

	(1)	(2)	(3)
Dependent variable		Wage growth	
Sample period	Jan 2021-Dec 2021	Jan 2021-Jun 2022	Jan 2021-Dec 2024
Average shortage in 2020	0.10**	0.16***	0.09***
	(0.05)	(0.03)	(0.02)
Time FE	Yes	Yes	Yes
Adj R^2	0.09	0.16	0.11
Observations	120	240	480

Notes: *p<0.10, **p<0.05, ***p<0.01

[14] With flexible wage, wage should positively comove with vacancy rate, as higher vacancy rate improves workers' bargaining position.

A.4 Immigration and vacancy growth

Formally, we estimate the following regression:

$$\Delta v^i = \alpha + \beta imm^i + \epsilon^i, \tag{A-3}$$

where Δv^i represents the rate of change in sector i's vacancy rate between December 2021 and July 2024, and imm^i denotes sector i's change in foreign-born employment over the same period. The results are shown in Table A.3, immigration inflow is negatively and significantly correlated with vacancy growth.

Table A.3: Immigration inflow and vacancy growth

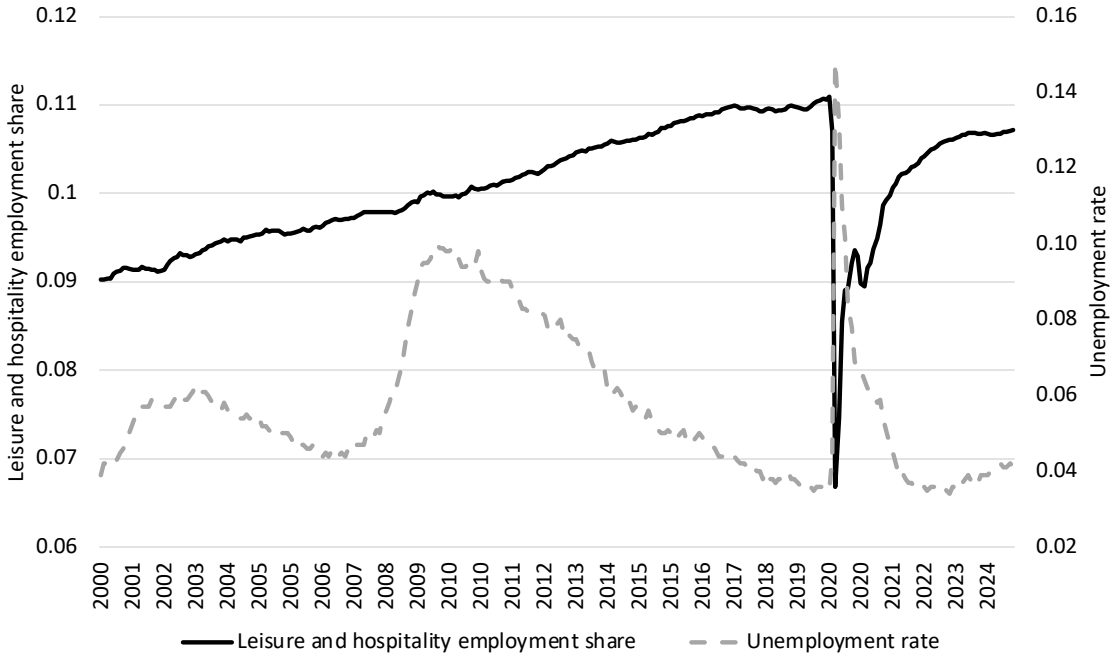
Dependent variable	Vacancy growth
Immigration net inflow	-0.46***
	(0.18)
Adj R^2	0.44
Observations	10

Notes: *p<0.10, **p<0.05, ***p<0.01.

A.5 Employment share in the Leisure & Hospitality sector

Figure A.2 shows the share of employment in the Leisure and Hospitality sector compared to total non-farm employment (solid line) and the non-farm unemployment rate (dashed line).

Figure A.2: Employment share of Leisure and Hospitality and unemployment rate



Source: Current Employment Statistics (Establishment Survey).

B Zero-shortage steady state

Once the labor shortage is fully resolved, the low-skilled sector reaches a no-shortage steady state, which is affected by the unemployment that accumulated during the shortage period, denoted by u^*. In this zero-shortage steady state, the employment level in the low-skilled sector is fixed as

$$N^{L*} = N^H. \tag{A-4}$$

The rates of job creation and job separation are both constant and equal:

$$p^* u^* \mu(\theta^*) = \delta N^L, \tag{A-5}$$

where the left-hand side indicates the count of surviving matches, while the right-hand side indicates job separations. Note that the count of newly formed matches is "excessive," resulting in a positive probability of match dissolution and $p^* < 1$. This is due to the larger labor force in the low-skilled sector compared to the high-skilled sector, which results from immigration inflows into the former during transitional periods.

The condition for free entry in the zero-shortage steady state can be derived as:

$$\theta^* = \frac{\beta \delta N^H J^*}{\kappa u^*}, \tag{A-6}$$

which corresponds to the second case of the free entry condition equation (10), with $\widetilde{\Delta} = \delta N^H$.

The Bellman equation for the job value for firms is:

$$J^* = \frac{(1-\tau)(z-h)}{1-\beta(1-p^*\mu(\theta^*)\tau-\delta)}, \tag{A-7}$$

which corresponds to the Bellman equation (16).

Given u^*, the steady-state levels of N^{L*}, J^*, p^*, and θ^* are jointly determined by equations (A-4)-(A-7).

C Model solution

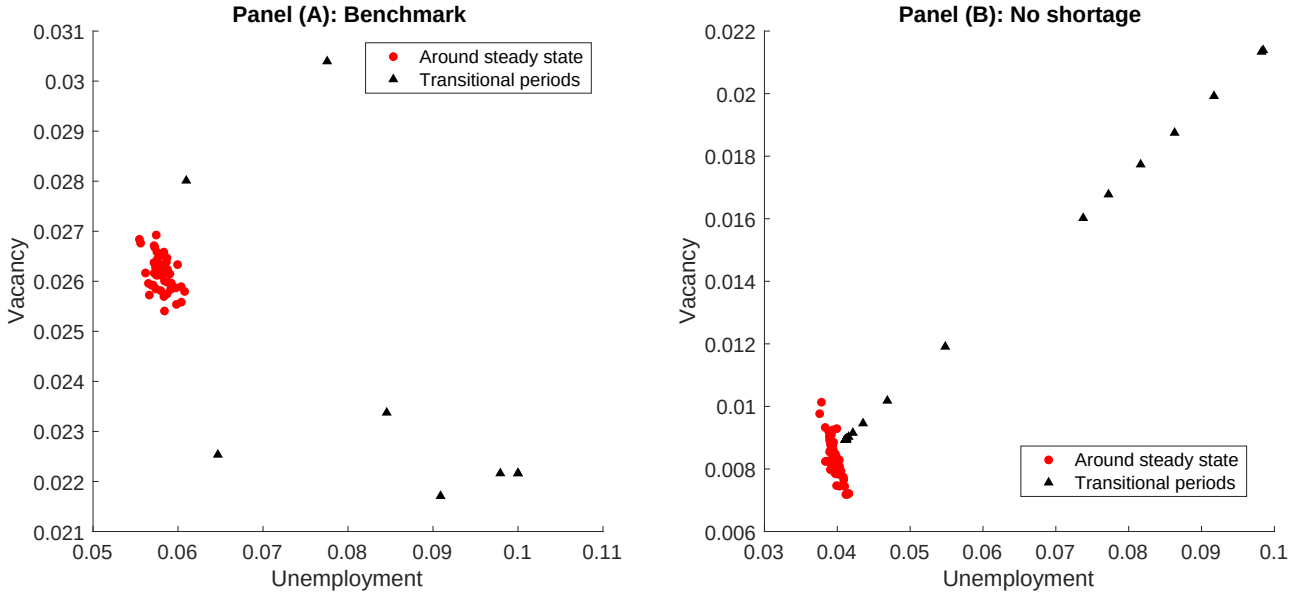
The model is nonlinear and solved numerically. The key unknowns to determine are the time when the labor shortage is fully resolved, called T, the probability that a new match stays intact throughout this period, called p_T, the series of job-finding rates before this period, represented as $\{\mu_t\}_{1\leq t\leq T}$, and the unemployment rate in the zero-shortage steady-state, denoted by u^*. All other variables can be determined from these unknowns.

To solve for these parameters, we initially set T, which is 50 in our exercise, but any positive integer can be selected. For this initial value, the system is assumed to stay in its zero-shortage steady state beyond T. We also set an initial value for u^*, which is 0.05 in our exercise. Equations (A-5)-(A-7) then determine J^*, p^*, and θ^*.

Next, we initialize p_T along with the series $\{\mu_t\}_{1\leq t\leq T}$. Using these initial values, the series $\{J_t\}_{1\leq t\leq T}$ is computed via equation (16). Based on the trajectory of J_t, we simulate the corresponding series for u_t, v_t, and Δ_t. The updated Δ_t is then used to refine T and p_T. With the new values of T, p_T, and u^*, iterations continue until the model converges.

D Beveridge curve

Figure D.3: Beveridge curves, model



Notes: Beveridge curve in the benchmark model (Panel A) and the counterfactual model with no labor shortage (Panel B).

To examine the effects of labor shortages and immigration on the combined dynamics of vacancies and unemployment, Figure D.3 shows the model-implied Beveridge curves for two scenarios. Panel A displays the results for the standard model with moderate immigration levels, while Panel B presents the counterfactual model without inter-sectoral complementarities and labor shortages.

In Panel A, the black triangles show the simulated vacancies versus unemployment from period 1 to period $T^* + 1$, where T^* is the time when the labor shortage ends. To highlight the unique endogenous joint dynamics of vacancies and unemployment during labor shortage periods, we also simulate the model around the zero-shortage steady state using discount factor shocks: $\beta_t = \beta\xi_t$.[15] Following Fernández-Villaverde et al. (2024a), We calibrate the discount factor shock using the Livingston Survey, which provides the median 12-month-ahead expected return r_t of the stock market index. The discount factor is computed as $\xi_t = 1/(1 + r_t)$. The

[15]Alternatively, we could simulate the model using productivity shocks. However, given a realistic calibration of the shock process, the impact of productivity shocks on vacancies and unemployment is relatively limited. See Shimer (2005) for a discussion

monthly AR(1) process that fits the series of ξ_t is specified as:

$$\log(\xi_t) = \rho_\xi \log(\xi_{t-1}) + \epsilon_{\xi,t}, \quad \epsilon_{\xi,t} \sim \mathbf{N}(0, \sigma_\xi^2),$$

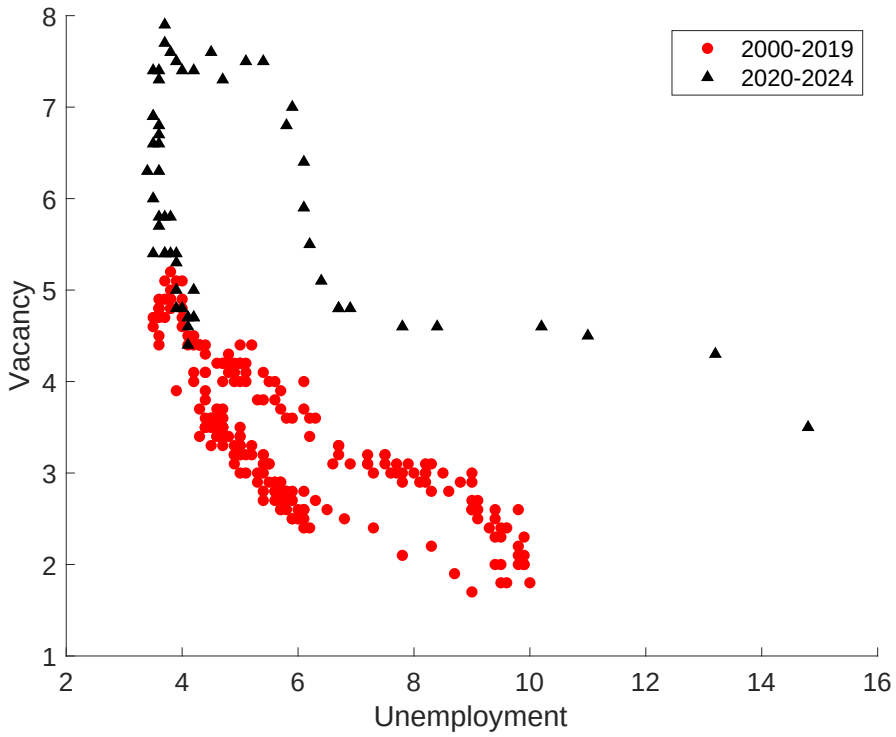
with parameters $\rho_\xi = 0.6$ and $\sigma_\xi = 0.054$. The red dots represent the scatter plot of the simulated vacancies against unemployment around the steady state for 50 periods.

The Beveridge curve shows distinct features during transitional periods (black triangles) and around the steady state (red dots). During transitional periods, the curve has a flat segment with low vacancies and relatively high unemployment, followed by a steep segment with low unemployment. This pattern is especially interesting because it closely matches the observed Beveridge curve since 2020, as shown in Figure D.4.

The counterfactual scenario without inter-sectoral complementarities and labor shortages is shown in Panel (B) of Figure D.3. The black triangles represent the initial 20 periods, during which the counterfactual model reaches the steady state, with the immigration inflow set equal to the benchmark case. The red dots illustrate the simulation around the steady state, driven by the discount factor shocks.[16] During the transition periods marked by the black triangles, the Beveridge curve shows an upward slope. This occurs because, when there are no labor demand shocks, the number of vacancies is directly related to the unemployment level.

[16]Note that the counterfactual model exhibits different steady states than the benchmark model.

Figure D.4: Beveridge curve, data



Notes: Beveridge curve data, 2020-2019.