Immigration and Unemployment:- A Macroeconomic Approach*

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Running Head: The Macroeconomics of Immigration

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Abstract:

This paper analyzes the effects of an unanticipated increase in immigration in a macroeconomic model with search and matching frictions. It shows how an immigration shock can lead to a temporary increase in unemployment under a variety of conditions and that this is qualitatively consistent with the responses from a VAR estimated on post-war US data.

Keywords : Macroeconomics, Immigration, Unemployment

1 Introduction

What are the effects on the macroeconomy of an unanticipated increase in immigration? This is an important theoretical consideration and, given the current events in Europe, is of practical interest as well. Immigration has been a significant part of US population growth over recent decades. In 1970 about 9.6 million (4.7%) of the US total population was foreign born to non-US nationals. In 2010 this number had risen to nearly 40 million or 12.9% of the US total population according to US Census Bureau and Current Population Survey (CPS) data. In this paper we take a macroeconomic perspective and examine the effect of shocks to the working population on the macroeconomy using a dynamic stochastic general equilibrium (DSGE) framework with labor market frictions. This paper shows in this context under a variety of conditions, that an increase in the working population can lead to a temporary increase in unemployment and that this is qualitatively consistent with the responses from a VAR estimated on post-war US data.

There is now a sizable literature analyzing the dynamic macroeconomic effects of immigration on the economy. Early examples of papers using the neoclassical growth model include Canova and Ravn (2000) who analyze the macroeconomic impact of regional migration from Eastern to Western Germany[1], Hazari and Sgro (2003) and Moy and Yip (2006) who focus on illegal or undocumented migration, and Palivos (2009) and Palivos and Yip (2010) who contrast the effects of migration on skilled and unskilled labor. Ben-Gad (2004, 2008) also develops a neoclassical growth model with overlapping dynasties to explore welfare consequences of legal immigration. More recently papers have incorporated labor markets with search and matching frictions into the analysis in order to investigate the impacts of migration on unemployment, see for example Liu (2010), Battisti et al. (2014), and Chassamboulli and Peri (2015).

The analysis closest to ours is the work of Chassamboulli and Palivos (2013, 2014), which finds that the job-creating response of firms to immigration leads to positive employment effects on natives. This is in line with the results in this paper. However, we also find that immigration causes a temporal increase in unemployment, while Chassamboulli and Palivos (2013, 2014) find the opposite effect. The source of this difference lies in the presence of a participation margin in our model so that, as we show below, immigration leads households to increase their labor supply in the transition to the new

[1]For recent macroeconomic analysis of regional migration, see Hauser (2014)'s analysis of US interstate migration.

steady state. This causes non-participants to enter the pool of job seekers resulting in a temporary rise in unemployment.

Specifically, this paper adapts the model of Brückner and Pappa (2012) (the BP model, hereafter), to allow for immigration shocks. The model is a Diamond-Mortensen-Pissarides model of search frictions (Diamond, 1982; Mortensen and Pissarides, 1994) in a macroeconomic labor market. There are heterogeneous workers who each face a labor force participation decision. Different worker types have different job matching probabilities and so different job finding rates. This heterogeneity allows us to analyze different scenarios about migrants' position in the labor market. Our baseline scenario assumes that migrants enter the labor market as unemployed workers with a low job matching probability. However we also examine scenarios where immigrants enter with a job and where they have a high job matching probability. In each case unemployment temporarily rises in response to an immigration shock, although the implications for different sections of the labor market differ across scenarios.

In this paper we treat immigration shocks as shocks to the labor supply and analyze their effects on the macroeconomy. As well as being intuitive, this interpretation of immigration is also consistent with the history of US immigration policy and the time series of its working population. Hatton (2015)'s analysis of US immigration policy finds that much immigration was unanticipated and that the effects of changes in policy were often the opposite to those intended by the policymakers.[2,3] We also show that the time series of the US working population, once corrected for the changes predicted by historical birth rate data, corresponds quite closely to immigration levels as measured by new permanent residents.[4]

The analysis and results of the paper are of interest for two distinct reasons. Firstly the macroeconomic DSGE literature has not paid the same level of attention to the determinants of the size of the working populations as it has to individual labor supply decisions.[5] This paper attempts to redress this imbalance by focussing on the macroeco-

[2]For example with regard to the 1965 Immigration Act, Hatton (2015) argues that the intention of the act was to increase the proportion of European migrants by expanding the family reunification immigration route, but the act actually had the opposite effect.

[3]Although some immigration may be anticipated, see e.g., Khraiche (2015). We analyze this case in section 4.2 below.

[4]As the work of Ramey (2011) details, correcting for anticipated changes in macroeconomic analysis is necessary to remove potential biases. See also Brezis and Ferreira (2016) and Doepke, Hazan and Maoz (2015) for the macroeconomic effects of endogenous fertility and the baby boom.

[5]For surveys of the literature see e.g., Uhlig (1999) or Christiano, Eichenbaum and Evans (2005).

nomic effects of immigration which, as noted above, has added over 30 million people to the US labor force since 1970 and is therefore one of the key determinants of changes in the total labor supply. Similarly while there is a large microeconomic literature on the effects of immigration on the labor market, there has been much less from a macroeconomic perspective.[6] There are good reasons for thinking that the macroeconomy is an appropriate level of analysis for investigating the effects of immigration. In a developed and integrated economy such as the US an inflow of labor into one region will affect the investment and labor flow into other regions and therefore the aggregate macroeconomy. If it makes sense to think of a macro economy with an aggregate production function, an aggregate capital stock, aggregate labor supply and an economy wide level of productivity then it makes sense to look at the effects of changes in the aggregate labor force.

The paper is organized as follows. In section 2 we present and discuss the data on immigration in the US since 1950. In section 3 we outline the model. Section 4 discusses the results of the simulation. Section 5 concludes.

2 Trends in US Working Population and Immigration

Immigration itself is not a factor of production. However, as we show in this section the time series of changes in the US working population, which are not predicted by historical birth rate data, corresponds quite closely to immigration levels as measured by the series for new permanent residents. Thus it is reasonable to consider an immigration shock as a shock to the working population as we do in the macroeconomic model below. In this section we first discuss the recent growth of the working population in the US and relate it to growth of immigration as measured by new permanent residents. We then show in a macroeconomic VAR that shocks to immigration are associated with temporary increases in unemployment and also short run increases in investment and decreases in GDP per

[6] See e.g., Card and Peri (2016) and Manacorda, Manning and Wadsworth (2012) for an excellent survey of the microeconomic literature. There is also a related macroeconomic literature on the macroeconomic effects of demographic change, see e.g., Bokan, Hughes Hallett, and Jensen (2016) and Sasaki and Hoshida (2016) on the effect of falling and even negative population growth for technological progress and debt dynamics. Kiguchi (2015) also analyzes the macroeconomic impacts of a policy of increasing population growth in response to an unexpected increase in the debt to GDP ratio.

capita and consumption, responses which are consistent with those of the macroeconomic model in section 3 below.

Changes in the Working Population and Immigration

Modern macroeconomic empirical and theoretical analysis describes macroeconomic fluctuations as responses to unanticipated changes in macroeconomic fundamentals. Birth data are publicly available and so a large proportion of the changes in the working population are not unanticipated as they can be observed 16 years ahead of time. Thus for consistency with the macroeconomic model in section 3 below we remove this predictable element from the working population series and construct an unanticipated change in population series using the series for working population in the US of Cociuba, Prescott and Ueberfeldt (2009) as a base.[7,8] If one compares this series with the series for new permanent residents in the US then one finds that although changes in the working population and new immigration flows are logically distinct, empirically they are highly related. The series have a similar pattern in that they both show a gradual rise from the 1950's to the 1980's and then a large increase in the latter period of the 1980's. The series are also similar in scale. Over the sample period 1950-2005 the cumulative unanticipated changes in the working population is approximately 38.2 million with 17.8 million occurring since 1990. The corresponding numbers for the new permanent residents series are 31.9 million and 15.7 million. One should not expect a perfect correspondence

[7] The construction uses the following formula

$$\begin{aligned} WPop_t^U &= WPop_t - WPop_t^A \\ \text{where } WPop_t^A &= (1 - \delta_{t-1}^{65} - mort_{t-1}^{16-64})WPop_{t-1} + (1 - mort_{t-16}^{1-15})Births_{t-16} \end{aligned}$$

where the $WPop_t$ is the series for working population in the US is taken from Cociuba, Prescott and Ueberfeldt (2009), $WPop_t^A$ is the anticipated working population in time which is equal to the previous year's working population minus the proportion aged 64 who will retire, δ_{t-1}^{65}, and the mortality rate of the working population plus the births from 16 years previously also adjusted for mortality. The adjustments are based on decennial averages and so are a little arbitrary but they serve their purpose.

[8] The sources of the data are the Centre for Disease Control's National Centre for Health statistics website <http://www.cdc.gov/nchs/>. Specifically for age specific mortality rates the data are from <http://www.cdc.gov/nchs/nvss/mortality/hist290a.htm>. For birth data the web address is <https://www.cdc.gov/nchs/data/statab/natfinal2003.annvol1_01.pdf>. The age distribution data is only available from the census from the website <http://www.census.gov/prod/www/decennial.html>. Since the census data is only decennial data we use linear interpolations to calculate the mortality rate of 1-15 years olds, 16-64 year olds and the proportion of retirees in the population in the formula above.

between these two series since one can attain new permanent resident status and not be part of the working population and vice versa. However the similarity between them is reassuring. To illustrate this we run a simple second order bivariate VAR of the two series and display the impulse responses in Figure 1. This shows that a positive shock to one series is associated with a positive shock to the other series.

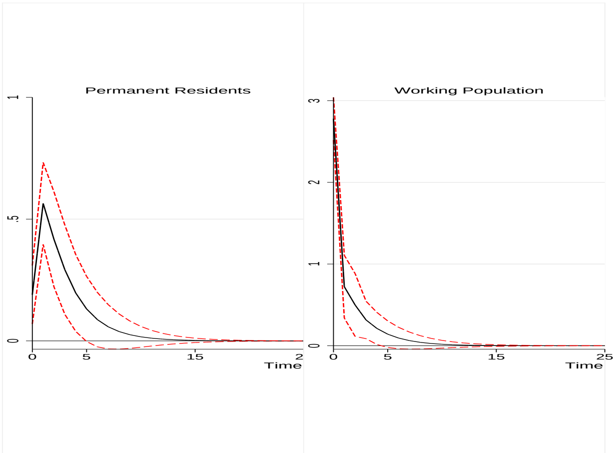


Figure 1: The correlation between the time series of new permanent residents and unanticipated working population series as illustrated by the Impulse Responses from a bivariate VAR identified by a Cholesky ordering with the unanticipated working population series ordered last. The one standard deviation confidence bands are shown.

Macroeconomic VAR

In this section we look at the empirical effects of immigration shocks using a VAR. We identify an immigration shock using sign restrictions and the condition that it is orthogonal to a business cycle shock which is also identified using sign restrictions. The impulses show that an immigration shock is associated with a temporary increase in unemployment and also temporary increases in investment and decreases in GDP per capita and consumption per capita which is consistent with the impulses in the theoretical model below.

We estimate an 8 dimensional VAR with annual data from 1950 to 2005 for the following variables; GDP, private consumption, non-residential investment, residential investment, unemployment, hours worked, real wages, and the numbers of new permanent

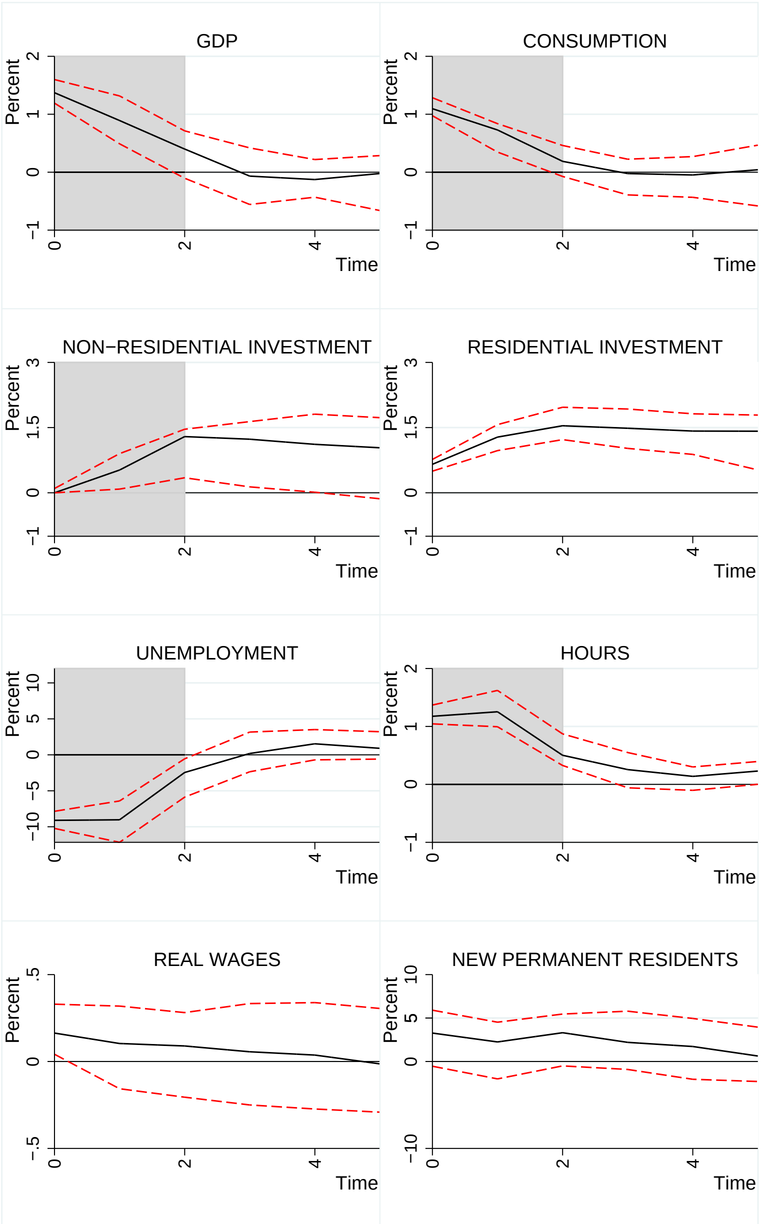


Figure 2: Impulse Responses to a business cycle shock identified via sign restrictions. The sign restrictions are indicated by the shaded areas. The one standard deviation confidence bands are shown.

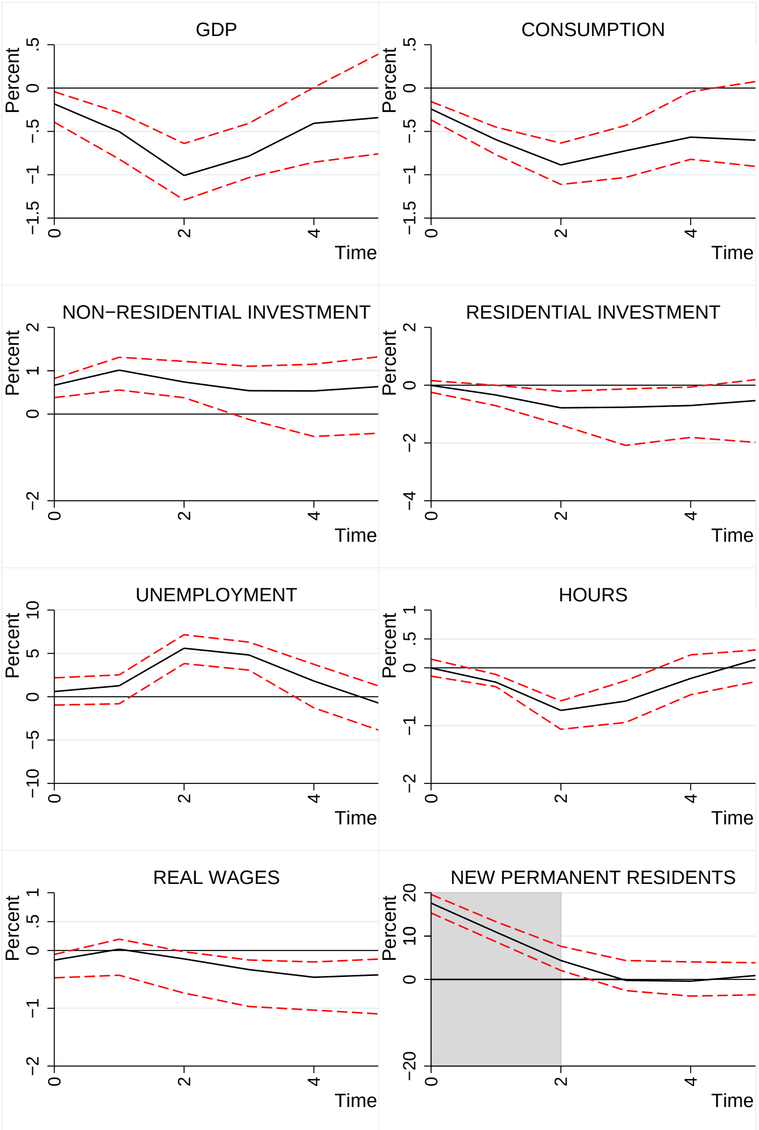


Figure 3: Impulse Responses to an immigration shock identified via sign restrictions and orthogonality to the business cycle shock. The sign restrictions are indicated by the shaded areas. The one standard deviation confidence bands are shown.

residents.[9] All variables are real and, with the exception of the wage series, expressed as per capita of the working population. The VAR has 2 lags, and uses the logarithm of the levels of all variables. The impulses responses of a business cycle shock are displayed in Figure 2 and those of the immigration shock are shown in Figure 3.

The business cycle shock is identified using a penalty function to restrict the signs of the responses of GDP per capita, consumption per capita, non-residential investment and hours to be positive and unemployment to be negative for two years after the shock. This approach allows the business cycle shock to explain the greatest amount of variation in these variables, see Mountford and Uhlig (2009) and more recently Caldara, Fuentes-Albero, Gilchrist and Zakrajšek (2016) for examples of this approach. Note that the identification does not restrict the response of immigration to this shock which is thus free to be either positive or negative. As Figure 2 shows there is some evidence that immigration is procyclical although the responses are not quite statistically significant.

The immigration shock is identified as being orthogonal to the business cycle shock and using a penalty function to restrict the signs of the responses of immigration to be positive for two years after the shock. These responses thus capture that part of the variation in the time series which is not explained by the business cycle shock and which is related to an increase in immigration. The responses in Figure 3 show that unemployment temporarily rises in response to an immigration shock. This is consistent with the responses to an immigration shock in the macroeconomic model described in the following section where unemployment rises in response to a shock before job vacancies respond sufficiently and unemployment converges back to its steady state level. The responses of GDP and consumption per member of the working population also resemble those from the model below. They initially fall as the denominator of their respective quotients increases faster than the numerator. They then recover as employment and output rise allowing their respective numerators to rise.

[9] The series or the macroeconomic data is taken from the FRED database and is series GDPXA, PCECCA, B008RG3A086NBEA, B011RG3A086NBEA, COMPRNFB, UNRATE with the exception of the working population and the hours worked series which come from Cociuba, Prescott and Ueberfeldt (2009) and the new permanent residents series which comes from the US Department of Homeland Security <https://www.dhs.gov/publication/yearbook-immigration-statistics-2012-legal-permanent-residents>.

3 A Macroeconomic Model with Immigration Shocks

In this section we analyze a macroeconomic model with immigration shocks. We show that while immigration shocks ultimately lead to job creation, in the short term they lead to temporary increases in unemployment and to temporary reductions in GDP per capita and consumption per capita. The increases in unemployment are not evenly spread across groups and those with a higher match finding probability may see their unemployment rate fall in response to an immigration shock.

The model extends the Brückner and Pappa (2012) (BP) model, to allow for immigration. The model includes households, firms (intermediate and retail), and a government which conducts both monetary and fiscal policy. Each household consists of a continuum of infinitely-lived employed workers, two types of unemployed workers (the short term and the long term unemployed), and non-participants. The short term and long term unemployed have differing job matching probabilities and job finding rates. Our baseline scenario assumes that migrants enter the labor market as unemployed workers with a low job matching probability and so that immigration is an exogenous shock to the number of unemployed workers. However we also examine scenarios where immigrants enter with a job and where they enter with a high job matching probability. We can interpret employment-based immigration as the case where employers sponsor immigrant workers for green cards based on their employment, while insider immigration can be viewed as immigration through a family member (i.e., family reunifications). In each of these cases total unemployment temporarily rises in response to an immigration shock, although the different initial position of the migrant in the labor market does effect particular sections of the labor market differently, as we will show below. Households supply labor services to the intermediate firms and earn wages when employed. When unemployed, households search for jobs and earn unemployment benefit, or enjoy leisure if not participating in a labor market. Intermediate firms hire workers in a frictional labor market, i.e., they increase their current workforce by posting vacancies, which is costly. They then produce intermediate goods by using capital and labor and sell the products to retailers, which differentiate them and sell to households in a competitive market. In the following, we explain the details of the model.

3.1 The Labor Force with Immigration

At any time of t, the number of household members who are employed is denoted by E_t, the number of short term unemployed (referred to as insiders) is denoted by U_t^I, the number of long-term unemployed (referred to as outsiders) is denoted by U_t^O, and the number of non-participants (i.e., out of labor force) is denoted by L_t.

At the beginning of the period we assume that there is an exogenous flow of immigratants into the host economy. In our baseline scenario we assume that newly immigrated people are likely to have less chances of finding jobs and so we treat them as outsiders in the labor market. We denote the number of migrants at time t as Mig_t, and assume that this follows a stationary stochastic process. The total population in the domestic economy, N_t, is therefore given by

$$N_t = E_t + U_t^I + U_t^O + Mig_t + L_t,$$

or equivalently,

$$1 = e_t + u_t^I + u_t^O + mig_t + l_t, \tag{1}$$

where e_t, u_t^I, u_t^O, mig_t, and l_t are proportions in the total population. In period $t+1$, the number of Mig_{t+1} are newly immigrated in the domestic economy, and therefore, the total population of the domestic economy evolves as

$$\begin{aligned} N_{t+1} &= N_t + Mig_{t+1} \\ \Leftrightarrow \frac{N_{t+1}}{N_t} &= \frac{1}{1 - mig_{t+1}} =: \zeta_{t+1}^N. \end{aligned}$$

3.2 Matching

The aggregate number of matches in the economy, M_t, is given by the sum of the constant-returns-to-scale matching function of insiders and of outsiders. The inputs to these matching functions are the vacancies that firms create and unemployed workers.

$$\begin{aligned} M_t =& M_t^I(V_t, U_t^I) + M_t^O(V_t, U_t^O + Mig_t) \\ =& \rho_m^I V_t^\alpha (u_t^I N_t)^{1-\alpha} + \rho_m^O V_t^\alpha ((u_t^O + mig_t)N_t)^{1-\alpha}, \end{aligned}$$

where V_t is the aggregate vacancy, and $\rho_m^I > \rho_m^O > 0$ is assumed. That is, insiders enjoy a more efficient matching technology than outsiders. The parameter $\alpha \in (0,1)$ is the elasticity of the matching function with respect to vacancies. The aggregate job finding rates for insiders and outsiders are defined respectively as

$$\gamma_t^{Ih} := \frac{M_t^I}{u_t^I N_t}, \tag{2}$$

$$\gamma_t^{Oh} := \frac{M_t^O}{(u_t^O + mig_t)N_t}, \tag{3}$$

and $\gamma_t^h := \gamma_t^{Ih} + \gamma_t^{Oh}$. The aggregate vacancy filling rate is

$$\gamma_t^f := \frac{M_t}{V_t}.$$

Using the job finding rates defined above, the transition equation for employment is expressed as

$$\begin{aligned} E_{t+1} &= (1-\sigma)E_t + M_t^I + M_t^O \\ \Leftrightarrow \widetilde{e}_{t+1}N_t &= (1-\sigma)e_t N_t + \gamma_t^{Ih}u_t^I N_t + \gamma_t^{Oh}(u_t^O + mig_t)N_t, \end{aligned} \tag{4}$$

where $\sigma \in (0,1)$ is the exogenous job destruction rate, and $\widetilde{e}_t := E_t/N_{t-1}$ represents employment per person at the beginning of time t. Similarly, the transition for insiders is given by

$$\begin{aligned} U_{t+1}^I &= (1-\mu)U_t^I + \sigma E_t - M_t^I \\ \Leftrightarrow \widetilde{u}_{t+1}^I N_t &= (1-\mu)u_t^I N_t + \sigma e_t N_t - \gamma_t^{Ih}u_t^I N_t, \end{aligned} \tag{5}$$

where $\mu \in (0,1)$ is the probability of becoming outsiders and $\widetilde{u}_t^I := U_t^I/N_{t-1}$.

3.3 Household

The household's total instantaneous utility function takes the form

$$u(c_t, l_t)N_t = \left(\frac{c_t^{1-\eta}}{1-\eta} + \Phi \frac{l_t^{1-\zeta}}{1-\zeta} \right) N_t,$$

where c_t is the consumption of each member of the household at time t, l_t, is defined in (1), and is the fraction of non-participants who enjoy leisure, $1/\eta$ is the intertemporal elasticity of substitution, ζ is the inverse of the Frisch elasticity of labor supply,

$\Phi > 0$ is a preference parameter that measures the disutility from being in the labor market. As is common in the macroeconomic literature, full risk sharing among household members is assumed so that they can insure themselves against income uncertainty and unemployment.[10] The household's problem is expressed as

$$\mathcal{J}(k_t, e_t, u_t^I, b_t) = \max_{c_t, k_{t+1}, b_{t+1}, e_{t+1}, u_{t+1}^I, u_t^O} \left(\frac{c_t^{1-\eta}}{1-\eta} + \Phi \frac{l_t^{1-\zeta}}{1-\zeta} \right) N_t$$
$$+ \beta \mathbb{E}_t \mathcal{J}(k_{t+1}, e_{t+1}, u_{t+1}^I, b_{t+1})$$

subject to total population (1), the job finding rates for insiders (2) and those of outsiders and (3), the law of motion for employed workers (4) and that of insiders (5), the following budget constraint (6), and the capital accumulation equation with adjustment costs (7):

$$c_t N_t + i_t N_t + \frac{b_{t+1} N_{t+1}}{p_t R_t} \leq r_t k_t N_t + w_t e_t N_t + ben(u_t^I + u_t^O(1 + mig_t)) N_t + \frac{b_t N_t}{p_t}$$
$$+ pro_t N_t - t_t N_t, \tag{6}$$

$$\widetilde{k}_{t+1} N_t = (1-\delta) k_t N_t + i_t N_t - \frac{\omega}{2} \left(\frac{\widetilde{k}_{t+1}}{k_t} - \zeta^N \right)^2 k_t N_t, \tag{7}$$

where i_t is investment, b_t is the government bond, R_t is the gross nominal interest rate, p_t is price level, w_t is real wage, r_t is the rental rate of capital, ben is unemployment benefits, pro_t is profits from firms, t_t is lump sum taxes, k_t is capital, $\delta \in (0,1)$ is the depreciation rate, ω captures the degree of adjustment costs, and $\widetilde{k}_t := K_t / N_{t-1}$.

As is common in the literature,[11] we define the marginal value to the household of having one member employed rather than unemployed, and that of being insider unemployed by using the first-order conditions to the household's problem above as follows:

$$V_t^E = -\Phi l_t^{-\zeta} N_t + c_t^{-\eta} w_t N_t + (1-\sigma) \beta \mathbb{E}_t \frac{V_{t+1}^E}{\zeta_{t+1}^N} + \sigma \beta \mathbb{E}_t \frac{V_{t+1}^{UI}}{\zeta_{t+1}^N}, \tag{8}$$

$$V_t^{UI} = -\Phi l_t^{-\zeta} N_t + c_t^{-\eta} ben N_t + \gamma_t^{Ih} \beta \mathbb{E}_t \frac{V_{t+1}^E}{\zeta_{t+1}^N} + ((1-\mu) - \gamma_t^{Ih}) \beta \mathbb{E}_t \frac{V_{t+1}^{UI}}{\zeta_{t+1}^N} \tag{9}$$

The marginal value to the household of an employed worker consists of the disutility from being in the labor market, $-\partial u(c_t, l_t) N_t / \partial l_t = -\Phi l_t^{-\zeta} N_t$, the wage rates, w_t, multiplied

[10] See, e.g., Merz (1995) and Andolfatto (1996).

[11] See, e.g., Ravn (2008), Shimer (2010) and Silva and Toledo (2009).

by the marginal utility of wealth $c_t^{-\eta}$ and the total numbers in household members, N_t, and the continuation value, which is the value of being employed if the match is not terminated, which occurs with the probability $(1-\sigma)$, and the value of becoming an insider if it is destroyed, which occurs with the probability σ. The continuation value is discounted by the discount factor, β, and adjusted by the expected population growth rate ζ_{t+1}^N. Similarly, the marginal value to the household of being an insider consists of the disutility from being in the labor market, and unemployment benefit, *ben*, and the continuation value. Note that an insider finds a job with the probability γ_t^{Ih}, as defined in (2), and remains an insider with the probability $((1-\mu)-\gamma_t^{Ih})$ since an insider becomes an outsider with the probability μ.

3.4 Intermediate Firms

Intermediate firms employ the aggregate household's labor E_t and aggregate capital, K_t, to produce goods.[12] The production function is given by:

$$Y_t = F(K_t, E_t) = K_t^{\varphi}(E_t)^{1-\varphi},$$

where $\varphi \in (0,1)$ is the elasticity of output with respect to capital. The value function of a firm with E_t currently employed workers is:

$$\mathcal{V}(E_t) = \max_{K_t, V_t} \; x_t F(K_t, E_t) - w_t E_t - r_t K_t - \kappa V_t + \mathbb{E}_t \Lambda_{t+1} \mathcal{V}(\underbrace{(1-\sigma)E_t + \gamma_t^f V_t}_{=E_{t+1}}), \tag{10}$$

where x_t is the relative price of intermediate goods, $\Lambda_{t+1} = \beta u_{ct+1}/u_{ct}$ is the stochastic discount factor, and $\kappa > 0$ is the cost of posting vacancies. The first-order conditions for K_t and V_t are;

$$\begin{aligned} [K_t]: \; & \varphi \, x_t \frac{Y_t}{K_t} = r_t, \\ [V_t]: \; & \frac{\kappa}{\gamma_t^f} = \beta \mathbb{E}_t \left(\frac{c_t}{c_{t+1}} \right)^{\eta} V_{t+1}^F, \end{aligned} \tag{11}$$

where V_t^F is the value of filling a vacancy which is defined as

$$V_t^F := (1-\varphi) x_t \frac{Y_t}{E_t} - w_t + (1-\sigma)\frac{\kappa}{\gamma_t^f}. \tag{12}$$

[12]The production function only has capital and labor as inputs and so abstracts from the effect of immigration in an economy with land as in e.g., Mountford (2004).

Therefore, the optimal vacancy condition (11), together with (12), states that the marginal cost of positing a vacancy should equal the expected marginal benefit, which is the marginal product of labor minus the wage plus the continuation value, knowing that the match can be terminated with probability σ.

3.5 Bargaining over Wages

The solution to the Nash bargaining problem can be written as the maximization of the weighted sum of log post-match surpluses:

$$\max_{w_t} \quad (1-\vartheta)\ln V_t^E + \vartheta \ln V_t^F,$$

where $\vartheta \in (0,1)$ denotes the firms' bargaining power. The first-order condition with respect to w_t leads to the following Nash wage equation:

$$w_t = (1-\vartheta)\left[(1-\varphi)x_t \frac{y_t}{e_t} + \frac{\kappa \gamma_t^{Oh}}{\gamma_t^f}\right] + \vartheta[ben - c_t^\eta \sigma \beta \mathbb{E}_t V_{t+1}^{UI}]. \tag{13}$$

The equilibrium Nash bargained wage is thus the weighted average of the marginal product of labor plus the value to the firm of marginal job (κ/γ_t^f), multiplied by the vacancy filling rate for an outsider, and the outside option of being unemployed minus the expected value of becoming an insider next period if the match is destroyed.

3.6 Retailers and Price Setting and Equilibrium Conditions

There is a continuum of monopolistically competitive retailers indexed by $i \in [0,1]$, which buy intermediate goods and differentiate them with a technology that transforms one unit of intermediate goods into one unit of retail goods. The relative price of intermediate goods, x_t, coincides with the real marginal cost that the retailers face. Final goods are expressed as the composite of individual retail goods Y_{it}:

$$Y_t = \left[\int_0^1 Y_{it}^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}},$$

where $\epsilon > 1$ is the elasticity of substitution between intermediate goods. Retail firms can optimize their price with a fixed probability $1-\chi^p \in (0,1)$ in any period following Calvo (1983), which will lead to the standard New Keynesian Phillips Curve:[13]

[13]See, e.g., Galí (2008) for the derivation.

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \lambda \widehat{x}_t,$$

where π_t is the inflation rate of prices of retail goods, and $\lambda = (1 - \beta\chi^p)(1 - \chi^p)/\chi^p$. A 'hat' over the marginal cost denotes the deviation from the steady state. Monetary policy follows an interest rate rule:

$$R_t = R \exp(\zeta_\pi \pi_t).$$

The government finances the expenditure on unemployment benefits and government spending by lump sum tax,

$$ben\ U_t + G_t = T_t.$$

and finally the resource constraint of the economy is given by

$$Y_t = C_t + I_t + G_t + \kappa V_t.$$

4 Simulation

4.1 Parameter Values

In the baseline calibration, we take the period in the model to correspond to a quarter and set the model parameters to fit the U.S. economy. The values are taken from Brückner and Pappa (2012) and are sumarized in Table 1. The new parameter introduced here, the steady-state immigration rate, mig, is set to 0.0057/4, following Ben-Gad (2012). The implies annual (gross) population growth rate is about 1.0057.

It is assumed that the discount factor $\beta = 0.99$ (implying an annualized steady-state real interest rate of approximately 4 percent), the relative risk aversion parameter $\eta = 2$, the capital share $\varphi = 0.3$, the Frisch elasticity of labor supply $\zeta = 4$, the elasticity of substitution $\epsilon = 6$ (implying a gross steady-state markup is equal to 1.2), the degree of price stickiness $\chi^p = 0.75$ (implying an average price duration of four quarters), and the capital depreciation rate $\delta = 0.01$ (implying annual depreciation rate of 4 percent), the capital adjustment cost $\omega = 2$, the coefficient on inflation in the interest rate rule $\zeta_\pi = 1.5$, and the steady-state value for government spending to output ratio $g/y = 0.18$.

For the labor market, total unemployment rate is set to 0.055, and according to CPS data, the share of the long-term unemployed in total unemployment is set to 0.16. We use the aggregate job finding rate $\gamma^h = 0.83$. The aggregate vacancy filling rate γ^f

is set equal to 2/3, and the participation rate is equal to $1 - l = 0.62$. The bargaining power of firms is set to 0.4. The Hosios (1990) condition is used to pin down the matching elasticity, so $\alpha = \vartheta$. Unemployment benefits ben and the average cost of hiring a worker κ are chosen to hit the target of 40 percent and 4.5 percent of the average quarterly wage of employed workers.

Table 1: Parameter Values

Parameter	Value	Description
m	0.0057/4	steady state immigration rate
$u/(n+u)$	0.055	total unemployment rate
u^O/u	0.16	share of outsiders in total unemployment
γ^h	0.83	aggregate job finding rate
γ^f	2/3	aggregate vacancy filling rate
$1-l$	0.62	participation rate
ϑ	0.4	relative bargaining power
α	0.4	elasticity of matching
ben/w	0.4	replacement rate
k/w	0.045	cost of vacancies as a % real wage
β	0.99	discount factor
φ	0.3	capital share
δ	0.01	capital depreciation rate
ζ	4	elasticity of labor supply
η	2	inverse of IES
ω	2	capital adjustment cost
$x = \epsilon/(\epsilon - 1)$	1.2	gross steady state markup
χ^p	0.75	degree of price stickiness
g/y	0.18	gov cons to GDP ratio
ζ_π	1.5	Taylor rule coefficient on inflation

4.2 The Effects of Immigration Shocks

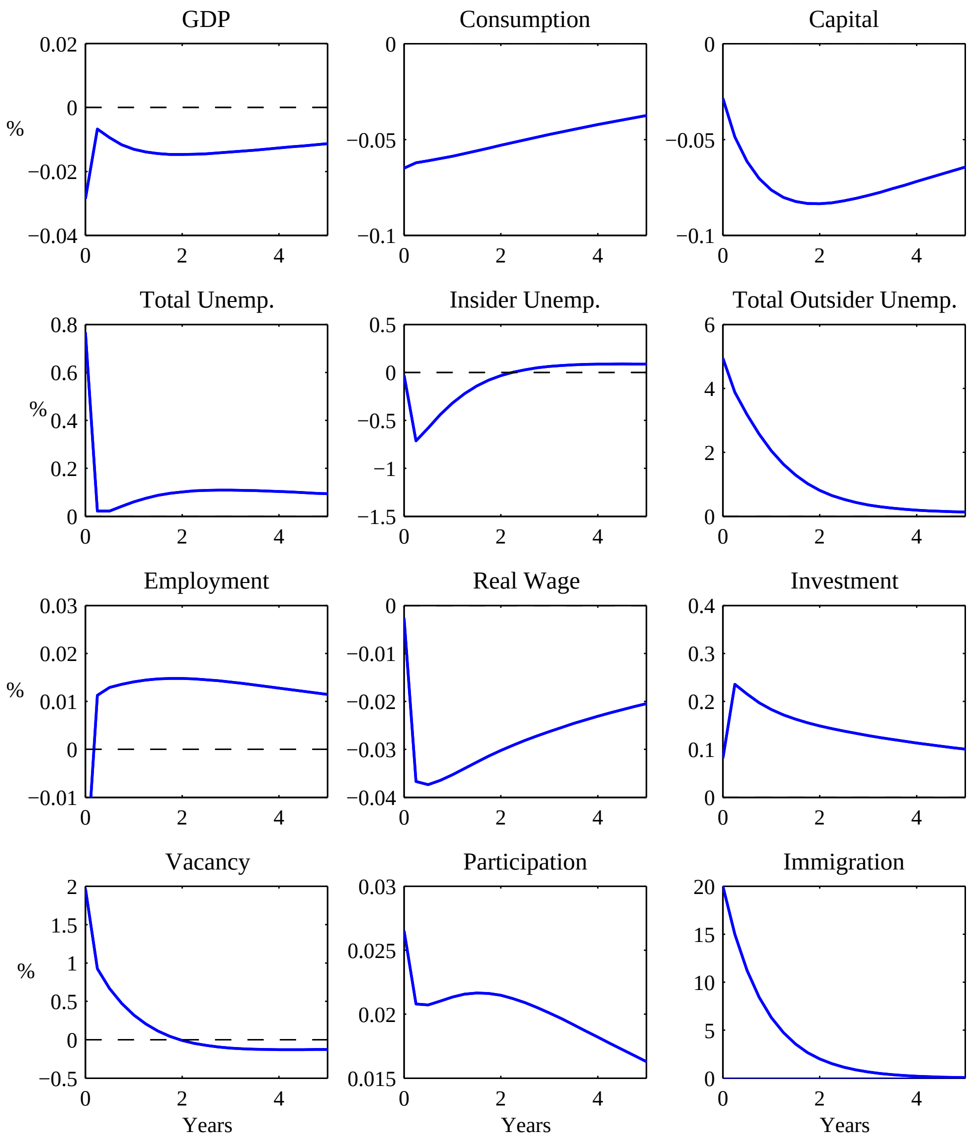
In this section we analyze the effects of an immigration shock to the macroeconomy. The immigration shock is an increase of 20 percent in ϵ^{mig}_{t+1} in equation (a) in Table

2 in Appendix A, which corresponds to an initial increase of about 0.03 percent in population. The autoregressive coefficient, ρ_m, is set to 0.75. These values are chosen to roughly capture the immigration shock in Figure 3.

We first present the benchmark case where migrants enter as outsiders in the labor market, and wages are flexible. The impulse responses to this case are displayed in Figure 4. We then discuss the case where wages are rigid and again where migrants enter as outsiders in the labor market. The impulses to this case are displayed in Figure 5. In both cases the effect of immigration shocks is to temporarily increase unemployment with the effect being large and more persistent under rigid wages than under flexible wages. In Appendix B, we also consider the cases where migrants enter as insiders in the labor market and enter as employed workers. In each case immigration shocks lead to a temporary increase in unemployment although the distribution of unemployment across outsiders and insiders differs across the specifications. Finally we consider anticipated immigration. The responses for this case are displayed in Figure 6 and show that unemployment and vacancies also rise in this case but on announcement i.e. before the working population itself actually rises.

Figure 4 displays the short-run dynamics of twelve macroeconomic variables (GDP, consumption, capital, total unemployment, insider unemployment, outsider unemployment, employment, real wage, investment, vacancy, participation rate, and immigration) produced by the benchmark model. It shows that an immigration shock generates an instantaneous rise in outsider unemployment, by assumption in this case, and this leads to a fall in the job finding rate for outsiders (not shown). The decline in job finding rate for outsiders causes the real wage to decline following the Nash bargaining equation (13). This in turn creates an incentive for firms to post more job vacancies since the marginal benefit of positing vacancies, and hence, the value of filling a vacancy has increased. As insiders have a higher matching probability they also have a higher job finding rate and so the unemployment rate amongst insiders falls. However the unemployment of outsiders increases and for total unemployment this effect dominates. Thus both employment and the total unemployment increase temporarily. Immigration also causes a reduction in capital per person (the "capital dilution effect"). This creates another downward force on real wages and causes households to reduce consumption and increase labor supply in order to increase investment and rebuild capital. Consequently GDP per capita and consumption per capita fall, and participation rates rise in response to an immigration shock. Interesting this was also the case in the maximum likelihood responses in the

Figure 4: Dynamic Responses to an Immigration Shock: Benchmark



VAR, which are shown in Figure 3.

Rigid Wages

The possibility of rigid wages is regarded by many to be a more realistic description of the labor market. The literature has also shown how wage rigidity can help explain important labor market and macroeconomic phenomena. Notable examples include unemployment variability over the business cycle, Hall (2005), inflation and unemployment dynamics, Blanchard and Galí (2010), and asset price behavior, Uhlig (2007). It is thus natural that we consider how wage rigidity impacts on our analysis of the effect of immigration shocks on the macroeconomy. We find that wage rigidity reinforces the findings of the baseline scenario in that the unemployment caused by immigration shocks is both higher and more persistent than in the baseline case.

We introduce a simple wage rigidity rule to the benchmark model following Shimer (2010).The wage is expressed as a weighted average of the wage in the previous period and the Nash bargained wage in this period:

$$w_t = \chi^w w_{t-1} + (1 - \chi^w) w_t^{Nash},$$

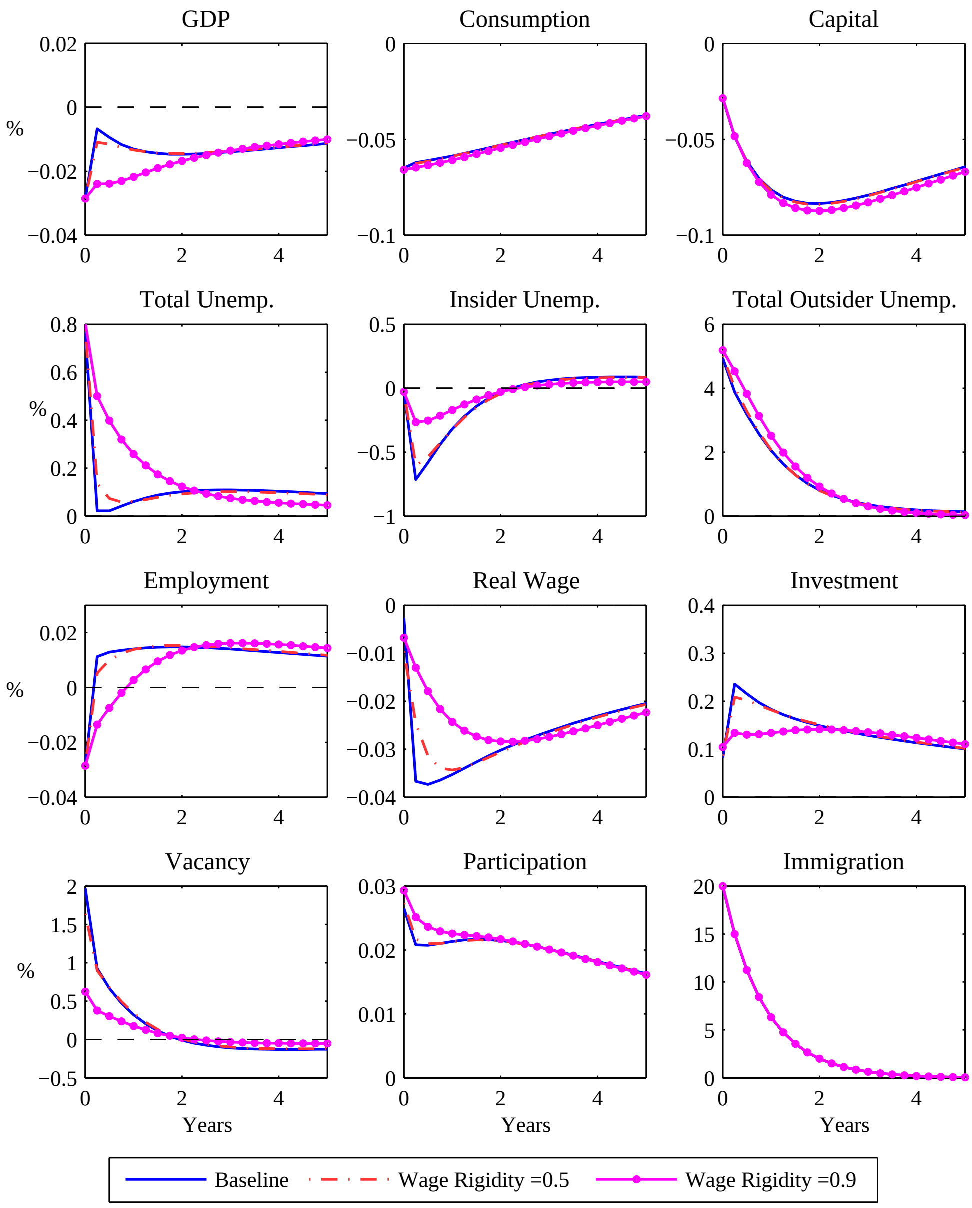
where $\chi^w \in [0, 1]$ denotes the degree of wage stickiness and w_t^{Nash} is a Nash bargained wage given by (13). When $\chi^w = 0$, wages are flexible, and therefore, the model corresponds to the benchmark one.

Figure 5 plots the impulse responses following a shock to immigration in the presence of the wage rigidity for alternative parameter for wage rigidity, $\chi^w = 0$ (baseline), 0.5, or 0.9. According to Figure 5, the presence of wage rigidity leads to more gradual declines in real wage, and so a smaller increase in job vacancies. Consequently, as stated, the unemployment rate of insiders as well as total unemployment are higher and more persistent in response to an immigration shock than in the baseline, flexible wage, scenario.

Anticipated Migration

The model is also able to analyze anticipated immigration where there is no initial immigration but where immigration is expected in the future. Hanson and McIntosh (2010, 2012) argue that anticipated immigration plays a role in immigration to the US from Mexico and Latin America. Figure 6 plots the impulse responses following an

Figure 5: Dynamic Responses to an Immigration Shock with Rigid Wages

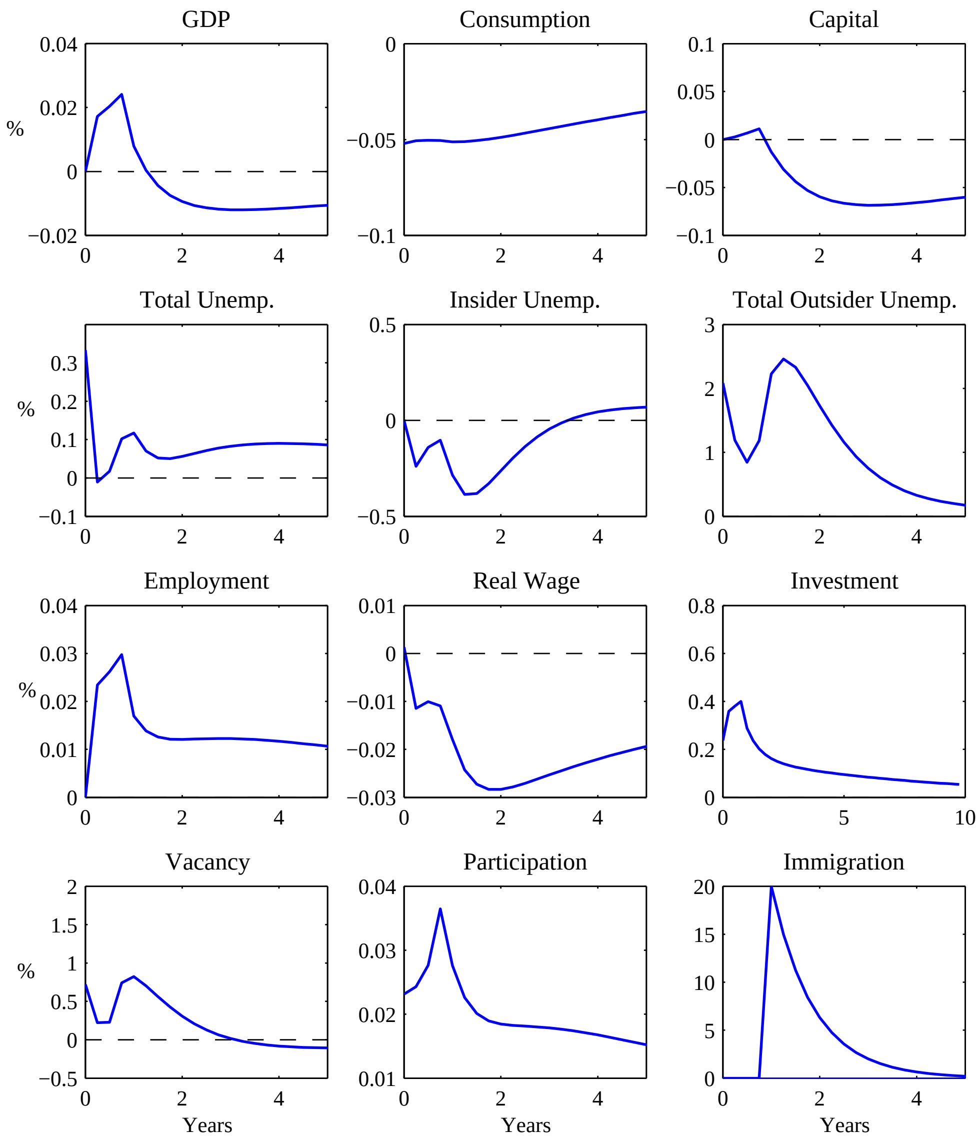


anticipated shock to immigration where immigration only starts to occur in a year's time. The same effects are still present in this case as with the unanticipated ones above. Anticipated immigration still causes unemployment, vacancies and investment to rise for the same reasons as above. However the difference in this case is that they now rise on announcement i.e., before the increase in working population actually occurs. This leads GDP per capita to rise on impact, only declining when the immigrants arrive. Note that the sign restriction methodology for the empirical VAR in section 2 restricts signs over a two year period and so capture both anticipated and unanticipated shocks with its identification strategy. The impulses responses in Figure 3 are closer to those in Figure 4 for an unanticipated immigration shock than those in Figure 6 which may imply that unanticipated shocks are the more relevant empirically.

5 Conclusion

In this paper we have argued that post-war immigration into the United States can be treated as an autoregressive process whose innovations are shocks to the US working population. We have analyzed the effects of immigration shocks using a dynamic macroeconomic model with search and matching frictions and shown how immigration shocks lead to a temporary rise in unemployment and a temporary fall in GDP per capita. Results which are consistent with both the data and intuition.

Figure 6: Dynamic Responses to an Anticipated Immigration Shock



Appendix

A. List of Log-linearized Equations

We log-linearize per-capita equations around the steady state. We denote log-deviations by hats over variables so that for a generic aggregate variable X_t, $\widehat{x}_t = \log(x_t) - \log(x) \approx (\widetilde{x}_t - x)/x$ where $x_t := X_t/N_t$ and x is the steady state value of x_t. The only exception is the inflation rate, π_t, which is expressed as a percentage deviation from the steady state of zero inflation, so that $\widehat{\pi}_t = \pi_t$. The log-linearized dynamics of the model is shown in Table 2 on the following page. Equations (1) to (27) determine 27 endogenous variables: $y_t, c_t, i_t, k_t, \widetilde{k}_t, r_t, e_t, \widetilde{e}_t, u_t^I, \widetilde{u}_t^I, u_t^O, l_t, w_t, R_t, x_t, \pi_t, m_t^I, m_t^O, v_t$, γ_t^{Ih}, γ_t^{Oh}, γ_t^{If}, γ_t^{Of}, γ_t^{f}, λ_{et}, λ_{ut}, ζ_t^N. Equation (a) represents an exogenous process.

Table 2: The Log-Linearized Equations of the Model (log-deviations are denoted by hats)

(1)	$\widehat{\widetilde{e}}_{t+1} = \left(\frac{1-\sigma}{\zeta^N}\right)\widehat{e}_t + \left(\frac{m^I}{e\ \zeta^N}\right)\widehat{m}_t^I + \left(\frac{m^O}{e\ \zeta^N}\right)\widehat{m}_t^O$
(2)	$\widehat{e}_t = \widehat{\widetilde{e}}_t - \widehat{\zeta}_t^N$
(3)	$\widehat{m}_t^I = \alpha\widehat{v}_t + (1-\alpha)\widehat{u}_t^I$
(4)	$\widehat{m}_t^O = \alpha\ \widehat{v}_t + (1-\alpha)\left[\frac{u^O}{u^O+mig}\ \widehat{u}_t^O + \frac{mig}{u^O+mig}\ \widehat{mig}_t\right]$
(5)	$\widehat{\gamma}_t^{Ih} = \widehat{m}_t^I - \widehat{u}_t^I$
(6)	$\widehat{\gamma}_t^{Oh} = \widehat{m}_t^O - \frac{u^O}{u^O+mig}\ \widehat{u}_t^O - \frac{mig}{u^O+mig}\ \widehat{mig}_t$
(7)	$\widehat{\widetilde{k}}_{t+1} = \left(\frac{1-\delta}{\zeta^N}\right)\widehat{k}_t + \left(1-\frac{1-\delta}{\zeta^N}\right)\widehat{i}_t$
(8)	$\widehat{k}_t = \widehat{\widetilde{k}}_t - \widehat{\zeta}_t^N$
(9)	$\widehat{\widetilde{u}}_{t+1}^I = \left(\frac{1-\mu}{\zeta^N}\right)\widehat{u}_t^I + \sigma\left(\frac{e}{u^I\zeta^N}\right)\widehat{e}_t - \left(\frac{m^I}{u^I\zeta^N}\right)\widehat{m}_t^I$
(10)	$\widehat{u}_t^I = \widehat{\widetilde{u}}_t^I - \widehat{\zeta}_t^N$
(11)	$0 = e\widehat{e}_t + u^I\widehat{u}_t^I + u^O\ \widehat{u}_t^O + mig\ \widehat{mig}_t + l\widehat{l}_t$
(12)	$\frac{\eta}{\beta}\widehat{c}_t + \frac{\omega\zeta^N}{\beta}\widehat{k}_t = \mathbb{E}_t\left[\frac{\eta}{\beta}\widehat{c}_{t+1} - r\widehat{r}_{t+1} - \omega(\zeta^N)^2\widehat{\widetilde{k}}_{t+2} + \frac{w\zeta^N}{\beta}\widehat{\widetilde{k}}_{t+1} + \omega(\zeta^N)^2\widehat{k}_{t+1}\right]$
(13)	$\frac{\gamma^{Oh}\lambda_e}{\gamma^{Oh}\lambda_e+c^{-\eta}ben}(\widehat{\gamma}_t^{Oh} + \widehat{\lambda}_{et}) - \frac{c^{-\eta}ben\eta}{\gamma^{Oh}\lambda_e+c^{-\eta}ben}\widehat{c}_t = -\zeta\widehat{l}_t$
(14)	$\lambda_u\widehat{\lambda}_{ut} = \beta\mathbb{E}_t[-c^{-\eta}ben\eta\widehat{c}_{t+1} + \gamma^{Ih}\lambda_e\widehat{\lambda}_{et+1} + \lambda_u[(1-\mu) - \gamma^{Ih}]\widehat{\lambda}_{ut+1}$
	$+\gamma^{Ih}[\lambda_e - \lambda_u]\widehat{\gamma}_{t+1}^{Ih} + \Phi l^{-\zeta}\zeta\widehat{l}_{t+1}]$
(15)	$\lambda_e\widehat{\lambda}_{et} = \beta\mathbb{E}_t[-\eta c^{-\eta}w\widehat{c}_{t+1} + c^{-\eta}w\widehat{w}_{t+1} + (1-\sigma)\lambda_e\widehat{\lambda}_{nt+1} + \sigma\lambda_u\widehat{\lambda}_{ut+1} + \Phi l^{-\zeta}\zeta\widehat{l}_{t+1}]$
(16)	$\widehat{c}_t = \mathbb{E}_t\widehat{c}_{t+1} - \frac{1}{\eta}(\widehat{R}_t - \mathbb{E}_t\widehat{\pi}_{t+1})$
(17)	$\widehat{y}_t = \varphi\widehat{k}_t + (1-\varphi)\widehat{e}_t$
(18)	$\widehat{\gamma}_t^{If} = \widehat{m}_t^I - \widehat{v}_t$
(19)	$\widehat{\gamma}_t^{Of} = \widehat{m}_t^O - \widehat{v}_t$
(20)	$\frac{\kappa}{\beta\gamma^f}\widehat{\gamma}_t^f + \frac{\kappa\eta}{\beta\gamma^f}\widehat{c}_t = \frac{\kappa\eta}{\beta\gamma^f}\mathbb{E}_t\widehat{c}_{t+1} + (1-\varphi)x\frac{y}{e}\mathbb{E}_t(\widehat{e}_{t+1} - \widehat{x}_{t+1} - \widehat{y}_{t+1}) + w\mathbb{E}_t\widehat{w}_{t+1} + (1-\sigma)\frac{\kappa}{\gamma^f}\mathbb{E}_t\widehat{\gamma}_{t+1}^f$
(21)	$w\widehat{w}_t = (1-\vartheta)(1-\varphi)x\frac{y}{e}(\widehat{x}_t + \widehat{y}_t - \widehat{e}_t) - \zeta\vartheta c^\eta\Phi l^{-\zeta}\widehat{l}_t - \vartheta c^\eta\sigma\lambda_u\widehat{\lambda}_{ut} + \vartheta c^\eta\eta(\Phi l^{-\zeta} - \sigma\lambda_u)\widehat{c}_t$
(22)	$\widehat{r}_t = \widehat{x}_t + \widehat{y}_t - \widehat{k}_t$
(23)	$\gamma^f\widehat{\gamma}_t^f = \gamma^{If}\widehat{\gamma}_t^{If} + \gamma^{Of}\widehat{\gamma}_t^{Of}$
(24)	$\pi_t = \beta\mathbb{E}_t\pi_{t+1} + \lambda\widehat{x}_t$
(25)	$\widehat{R}_t = \zeta_\pi\pi_t$
(26)	$\widehat{\zeta}_{t+1}^N = (mig/(1-mig))\widehat{mig}_{t+1}$
(27)	$\widehat{y}_t = \frac{c}{y}\widehat{c}_t + \frac{i}{y}\widehat{i}_t + \kappa\frac{v}{y}\widehat{v}_t + \frac{g}{y}\widehat{g}_t$
	Exogenous Processes
(a)	$\widehat{mig}_{t+1} = \rho_m\ \widehat{mig}_t + \epsilon_{t+1}^{mig}$

B. Extensions of the Model

In this section, we extend the baseline model in two ways. Firstly, by assuming that immigrants enter a host economy with jobs and secondly by assuming that immigrants enter as insiders. In each case the result of the paper that immigration shocks lead to a temporary increase in unemployment continues to hold although the distribution of unemployment across outsiders and insiders differs across the different specifications.

B1. Immigration with Jobs

If we consider an increase in immigration as an exogenous shock to the number of employed workers, then the transition of equation for employed workers is rewritten as

$$\begin{aligned} E_{t+1} &= (1-\sigma)E_t + (1-\mu_1)Mig_t + M_t^I + M_t^O \\ \Leftrightarrow \widetilde{e}_{t+1} &= (1-\sigma)e_t + (1-\mu_1)mig_t + m_t^I + m_t^O, \end{aligned}$$

where $\mu_1 \in (0,1)$ is the exogenous job separation rate. We assume that immigrants become outsiders when their jobs are terminated. The first-order conditions for household's problem are unaffected to this change. The Cobb-Douglas production function is now given by

$$Y_t = K_t^{\varphi}(E_t + Mig_t)^{1-\varphi}.$$

Thus, the marginal product of labor now becomes;

$$MPL_t := \frac{\partial Y_t}{\partial E_t} = (1-\varphi)\frac{Y_t}{E_t + Mig_t} = (1-\varphi)\frac{y_t}{e_t + mig_t}.$$

Note that an increase in immigration leads to a fall in the marginal product of labor if other things are equal. The resulting optimal vacancy posting condition is

$$\frac{\kappa}{\gamma_t^f} = \beta \mathbb{E}_t \left(\frac{c_t}{c_{t+1}}\right)^{\eta} \left[(1-\varphi)\frac{y_{t+1}}{e_{t+1} + mig_{t+1}} - w_{t+1} + (1-\sigma)\frac{\kappa}{\gamma_{t+1}^f}\right],$$

and Nash bargained wage is

$$w_t = (1-\vartheta)\left[(1-\varphi)x_t\frac{y_t}{e_t + mig_t} + \frac{\kappa\gamma_t^{Oh}}{\gamma_t^f}\right] + \vartheta ben - \vartheta c_t^{\eta}\sigma\beta\mathbb{E}_t V_t^{UI}.$$

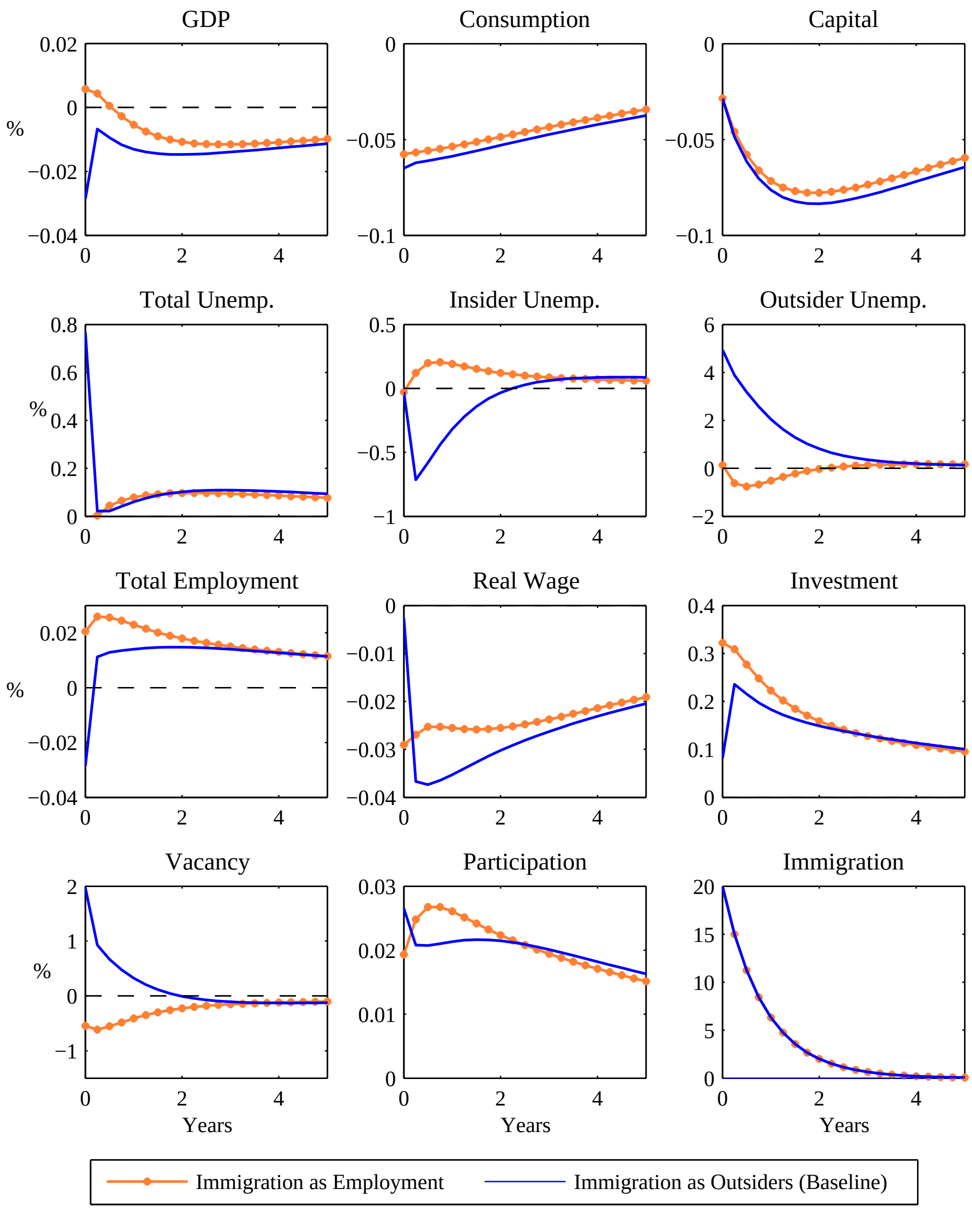
An increase in employed immigration has two counteracting effects on job vacancies. On one hand, it creates more incentives for firms to post vacancies by reducing the marginal product of labor, and hence, wage. On the other hand, the decrease in the marginal product of labor caused by employed immigration creates less incentives to open vacancies by reducing the marginal benefit of posting them.

The corresponding log-linearized equations are now given by

$$
\begin{aligned}
\widehat{\widehat{e}}_{t+1} =& \left(\frac{1-\sigma}{\zeta^N}\right)\widehat{e}_t + \left(\frac{mig}{e\,\zeta^N}\right)\widehat{mig}_t + \left(\frac{m^I}{e\,\zeta^N}\right)\widehat{m}_t^I + \left(\frac{m^O}{e\,\zeta^N}\right)\widehat{m}_t^O, \\
\widehat{y}_t =& \varphi\widehat{k}_t + (1-\varphi)\left[\frac{e}{e+mig}\,\widehat{e}_t + \frac{mig}{e+mig}\,\widehat{mig}_t\right], \\
\frac{\kappa}{\beta\gamma^f}\widehat{\gamma}_t^f + \frac{\kappa\eta}{\beta\gamma^f}\widehat{c}_t =& \frac{\kappa\eta}{\beta\gamma^f}\mathbb{E}_t\widehat{c}_{t+1} + (1-\varphi)\frac{y}{e+mig}\mathbb{E}_t\left[\left(\frac{e}{e+mig}\,\widehat{e}_t + \frac{mig}{e+mig}\,\widehat{mig}_t\right) - \widehat{x}_{t+1} - \widehat{y}_{t+1}\right] \\
&+ w\mathbb{E}_t\widehat{w}_{t+1} + (1-\sigma)\frac{\kappa}{\gamma^f}\mathbb{E}_t\widehat{\gamma}_{t+1}^f, \\
w\widehat{w}_t =& (1-\vartheta)(1-\varphi)x\frac{y}{e+mig}\left[\widehat{x}_t + \widehat{y}_t - \left(\frac{e}{e+mig}\,\widehat{e}_t + \frac{mig}{e+mig}\,\widehat{mig}_t\right)\right) \\
&- \zeta\vartheta c^\eta\Phi l^{-\zeta}\widehat{l}_t - \vartheta c^\eta\sigma\lambda_u\widehat{\lambda}_{ut} + \vartheta c^\eta\eta(\Phi l^{-\zeta} - \sigma\lambda_u)\widehat{c}_t.
\end{aligned}
$$

Figure 7 displays impulse responses to an immigration shock of the same magnitude as the baseline, but now immigrants are assumed to enter as employed workers. This employed immigration shock leads to a fall in real wage, which is similar to the prediction of the baseline model of outsider-immigrants. However, the model with employed immigrants predicts a decrease in job vacancies, while the model with outsider-immigrants predicts the opposite. In the baseline model, as is explained in Subsection 4.2, the main reason why an immigration shock increases job vacancies is that it causes job finding rate for outsiders to fall, which leads to negative pressure on real wage and a positive pressure on vacancies. In the model with employed immigrations, the effect of a reduction in the marginal benefit of posting vacancy due to a fall in the marginal product of labor dominates the effect of an increase in the marginal benefit due to a fall in real wage, and as a result of that, job vacancies decrease. This reduction of vacancies makes it harder for insiders to find jobs, and hence, unemployment of insiders increases. Unemployment of outsiders also increases on the impact. This is because non-participants reduces leisure and enter the labor market in order to increase consumption. However, it turns into slightly below the steady state by reflecting the fact they leave labor market and become non-participants. As a consequence, the model with employed immigration generates a slightly smaller impacts on total unemployment.

Figure 7: Immigration with Employment



B2. Immigration as Insiders

Next, we turn to the case where immigrations enter a host economy as insiders. In this case, the matching function for insiders is now given by

$$M_t^I = \rho_m^I V_t^\alpha [(u_t^I + mig_t)N_t]^{1-\alpha},$$

and hence, the job finding rate for insiders is

$$\gamma^{Ih} = \frac{M_t^I}{(u_t^I + mig_t)N_t} = \frac{m_t^I}{u_t^I + mig_t}.$$

The law of motion for insiders is replaced by

$$\begin{aligned} U_{t+1}^I &= (1-\mu)U_t^I + \sigma E_t - M_t^I + (1-\mu_2)Mig_t \\ \Leftrightarrow \widetilde{u}_{t+1}^I &= (1-\mu)u_t^I + \sigma e_t - \gamma_t^{Ih} u_t^I + (1-\mu_2)mig_t, \end{aligned}$$

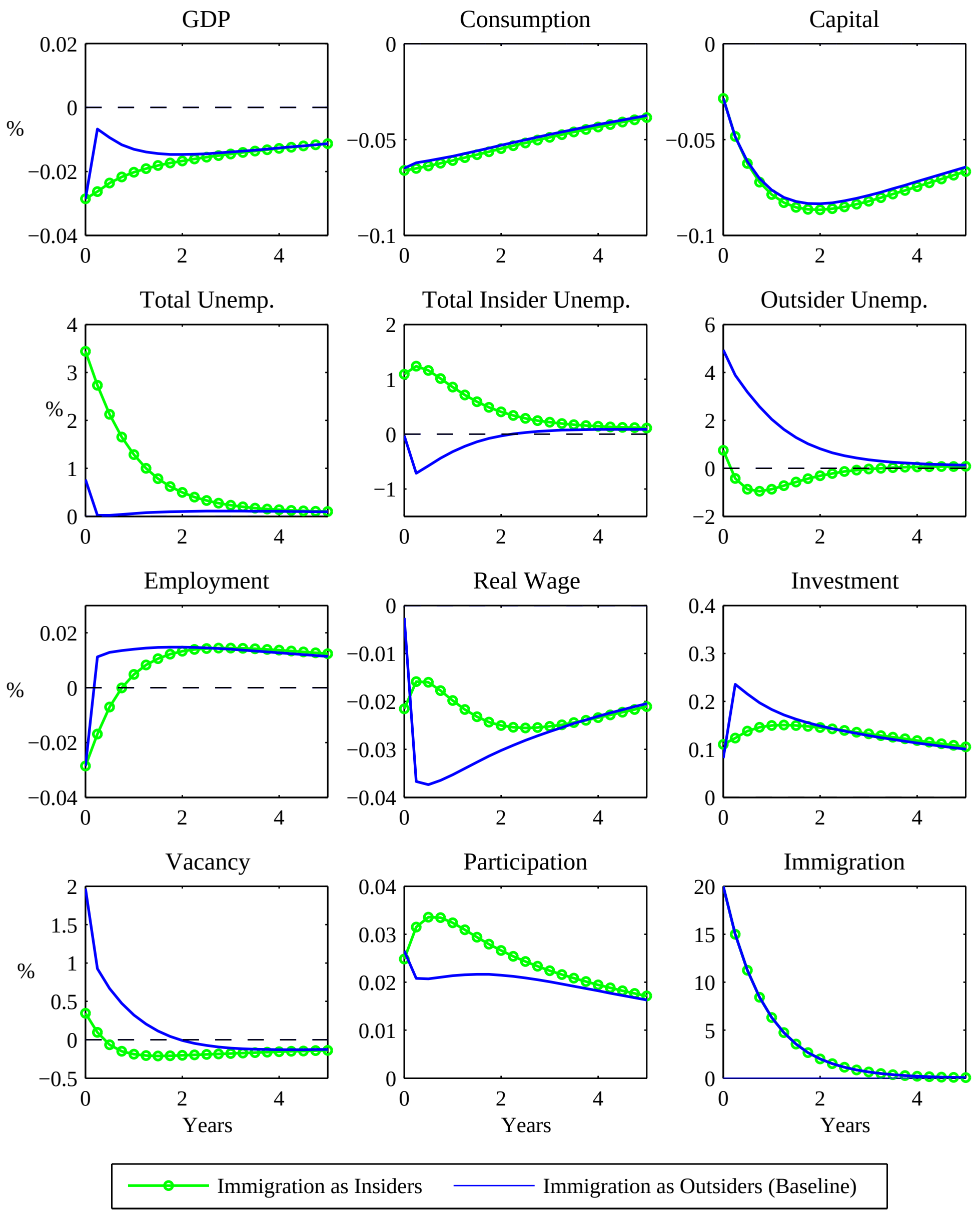
where $\mu_2 \in (0,1)$ is the probability that immigrants become outsiders.

As a result, the corresponding log-linearized equations are now replaced by

$$\begin{aligned} \widehat{m}_t^I &= \alpha\, \widehat{v}_t + (1-\alpha)\left[\frac{u^I}{u^I + mig}\, \widehat{u}_t^I + \frac{mig}{u^I + mig}\, \widehat{mig}_t\right], \\ \widehat{\gamma}_t^{Ih} &= \widehat{m}_t^I - \frac{u^I}{u^I + mig}\, \widehat{u}_t^I - \frac{mig}{u^I + mig}\, \widehat{mig}_t, \\ \widehat{\widetilde{u}}_{t+1}^I &= \left(\frac{1-\mu}{\zeta^N}\right)\widehat{u}_t^I + \sigma\left(\frac{e}{u^I\zeta^N}\right)\widehat{e}_t - \left(\frac{m^I}{u^I\zeta^N}\right)\widehat{m}_t^I + (1-\mu_2)\left(\frac{mig}{u^I\zeta^N}\right)\widehat{mig}_t. \end{aligned}$$

Figure 8 shows the dynamic responses to an immigration shock with the assumption that they enter a host economy as insiders. The magnitude of the shock as the same as the baseline model. For comparison, the responses of the baseline model are also displayed. An increase in immigration generates an increase in unemployment of insiders as we have assumed. On the impact, real wage falls due to a fall in the marginal value of being an insider, leading to an instantaneous rise in vacancies. After that, however, vacancies show a gradual decrease and turn into slightly below the steady state level since the marginal cost of a vacancy increases gradually due to a fall in the vacancy filling rate (not shown). Unemployment of outsiders also declines gradually slightly after an initial rise, reflecting the fact that job finding rate for outsiders decline since some of them leave the labor market. Less increase in vacancies leads to less increase in employment, and hence, larger total unemployment.

Figure 8: Immigration as Insiders



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