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Abstract

This paper constructs a multi-sector dynamic general equilibrium model for a trading economy. We incorporate three major factors of production: capital, skilled labor & unskilled labor. We solve and calibrate the model using data from Japan. We then consider changes to immigration policy. We are able to examine the effects on output, consumption, factor prices and utility. We do this for both the new steady state and for the time-path leading to that steady state. In addition, we impose a series of unrelated macroeconomic shock to the model. This has the advantage of allowing us to calculate confidence bands around our policy impulse response functions.

We find that allowing more skilled relative to unskilled labor to immigrate leads to greater welfare gains in the steady state. However, even with exclusively unskilled immigration, existing workers are made better off on average when immigration restrictions are relaxed. We show that there is a great deal of uncertainty surrounding the exact time path to a new steady state in the presence of the typical fluctuations associated with business cycles. We also find a great deal of inertia in the transition to a new steady state.

1. Introduction and Literature Review

Immigration issues are among the most politically sensitive economic issues confronted by policy makers. Whether or not to allow workers from low wage countries to migrate to high wage countries is a source of constant domestic and international political debate. Western Europeans struggle with the optimal number of workers from Eastern Europe, North Africa and the Middle East. Americans confront issues of immigration from Mexico and other parts of Latin America, as well as from China and other countries in Asia. By comparison, immigration issues do no loom so large in Japan. Nonetheless, Japan's aging population and low birthrates have led to debate in Japanese policy circles on the wisdom on allowing foreign workers into the country. In addition, as incomes have risen, the lure of higher wages has made Japan a more attractive place for non-Japanese laborers to work. Japanese firms find the lower wages that immigration would induce attractive. Japanese workers find this correspondingly unattractive.

Japan has been strict in limiting immigration, particularly when compared to other countries with similar standards of living. Japanese immigration law favors skilled workers and those with Japanese ancestry. This is at least partly because of concerns of possible links between non-assimilation of low wage workers and crime. There is no consensus at the current time on whether immigration restrictions should be eased or not. Advocates of the status quo argue that available jobs can largely be filled by Japanese workers[1]. And it is true that labor force participation rates for Japanese women, youth, and the elderly are lower than other developed countries. Advocates of increased immigration argue that Japan's demographics demand an increase in immigration to fill job openings and support an increasingly older population.

Some observers of Japan's immigration policy argue that rather than increases or decreases in immigration quotas, the government needs to focus on consistent enforcement of a simple set of immigration rules.[2]

In this paper we examine the effects of various broad changes to immigration policy in Japan. We build and calibrate a multi-sector dynamic stochastic general equilibrium (DSGE)

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[1] See Makoto (2004), for example.

[2] See Kuwahara (2004) and Tezuka (2004).

model and consider changes in the supply of both unskilled and various types of skilled labor. We are interested in the effects these policy changes will induce on the welfare of existing domestic workers and on the aggregate effects on output, consumption and other key measures of economic activity. We find that immigration raises overall consumption per capita only if the share of skilled labor in total immigration is sufficiently high. This finding would seem to validate the government's policy of preferential treatment to skilled workers. However, we also show that the consumption of Japanese workers will rise even with purely unskilled immigration. It is still true that policies which favor skilled workers raise consumption and utility more that policies which favor unskilled immigrants.

This paper is not the first to examine these issues using formal computable models. Goto (1998) builds and calibrates a small open computable general equilibrium (CGE) model for Japan. He groups goods into three categories: exportables, importables, and nontraded. Rather than aggregating into a single final good, he allows each of these to enter the utility function separately. Since the model is not explicitly dynamic, he holds capital in each production sector constant. Labor, however, is homogenous and mobile across sectors. Goto examines the effects of several shocks having to do with changes in trade and international prices. His most interesting result is that small amounts of labor immigration reduce welfare, while sufficiently large amounts may improve welfare.

Choi (2004) builds a static general equilibrium model of the South Korean economy. His model is similar in spirit to ours, but has important differences in the modeling. He allows for imperfect competition in intermediate goods which are produced using sectorally-mobile capital and skilled labor which is specific to that particular intermediate good. Final goods are perfectly competitive and produced with capital and unskilled labor. Choi focuses on the welfare effects of easing immigration restrictions and is concerned primarily with behavior in the short run as a result of business cycle movements. He reports the effects of various business cycle shocks to the economy on welfare and wage inequality.

In contrast, this paper is explicitly dynamic and uses the tools of DSGE modeling. We focus on the long-run transition to a new steady state equilibrium. Business cycle movements are important only because they add uncertainty and volatility to this transition. By incorporating these shocks, however, we are able to present not only impulse responses of key variables to immigration shocks, but also derive confidence bands about these responses.

Section 2 below presents the model. Section 3 shows how it can be rendered stationary and suitable for finding a steady state. In section 4 we discuss calibration of the model and discuss possible policy changes. Our policies differ in the mix of skilled and unskilled workers that are allowed to immigrate. Section 5 explains the technique for finding linear approximations of the policy functions that govern the dynamics of our simulated model. We simulate the various policy options and derive both smooth transition paths as well as ones with confidence bands for the key variables considered. Section 6 concludes the paper.

2. The Model

We construct a small open economy multi-sector dynamic general equilibrium model. Our model allows for a single non-traded final good (Y) which is used for consumption (C) & investment in capital goods. It is produced using five intermediate goods via an Armington aggregator. The intermediate goods (Y_i) may be traded internationally or may be non-traded depending on their nature. They are produced using capital (K) & two types of labor; skilled and unskilled (N). Each type of skilled labor (L_i) is unique to the good it produces and is therefore a specific factor. Unskilled labor can be used to produce any of the intermediate goods. All types of labor are supplied in fixed endowments. *C*apital is non-traded and accumulates optimally over time. Productivity (z_A) is exogenous and has both a trend and stochastic component. There is also a consumer confidence shock (z_R) which alters the household's perceived optimal time path for consumption and savings. Households may not save or borrow internationally and trade balances every period.[3]

Each period households maximize utility, supply capital and various forms of labor inelastically and save by holding physical capital. The typical consumer's problem is illustrated by the Bellman equation in (2.1) which is maximized subject to the budget constraint in (2.2).

$$V(K;\Theta) = \underset{K'}{\text{Max}}\ U(C) + \beta \text{E}\{e^{z_R{}'} V(K';\Theta')\} \tag{2.1}$$

[3] This is a constraint imposed by our linearization method, See McCandless (2008) chapter 13 for a good discussion of the issue.

$$C = \sum_i w_i \overline{L}_i + v\overline{N} + (1 + r - \delta)K - K' \tag{2.2}$$

In these equations, w_i is the wage rate for skilled labor of type i, v is the wage for unskilled labor, r is the rental rate for domestic capital, δ is the depreciation rate of capital, C is consumption, K is holdings of domestic capital, and Θ is the exogenous information set which includes prices, shocks, etc. A prime indicates the value of a variable one period from the current one.

With the assumption of a constant-elasticity-of-substitution (CES) utility function the first-order conditions reduce to the Euler equation in (2.3).

$$C^{-\sigma} = \beta \mathrm{E}\{e^{z_R'} C'^{-\sigma} (1 + r' - \delta)\} \tag{2.3}$$

Final producers maximize profits from purchasing all intermediate goods and producing final output, as shown in equation (2.4).

$$\underset{\{F_i\}}{\mathrm{Max}}\ \Pi_F = \prod_i F_i^{a_i} - \sum p_i F_i ; \sum_i a_i = 1 \tag{2.4}$$

Here, F_i is the quantity of intermediate good used and p_i is its real price.

The first-order conditions reduce to equations (2.5) and (2.6). The production function is an Armington aggregator and yields constant expenditure shares for each intermediate good in final production.

$$Y \equiv \prod_i F_i^{a_i} \tag{2.5}$$

$$p_i F_i = a_i Y \tag{2.6}$$

Intermediate producers maximize profits from hiring capital and labor and selling a particular intermediate good as in equation (2.7).

$$\underset{K_i, L_i}{\mathrm{Max}}\ \Pi_i = p_i K_i^{b_i} (e^{gt + z_A} N_i)^{c_i} (e^{gt + z_A} L_i)^{1 - b_i - c_i} - r_i K_i - w_i L_i - v_i N_i \tag{2.7}$$

Here, N_i is the unskilled labor demanded in sector i, L_i is the skilled labor demanded in sector i, and z_A is a technology shock. The first-order conditions reduce to equations (2.8) – (2.11).

$$r_i K_i = b_i p_i Y_i \tag{2.8}$$

$$v_i N_i = c_i p_i Y_i \tag{2.9}$$

$$w_i L_i = (1 - b_i - c_i) p_i Y_i \tag{2.10}$$

$$Y_i \equiv K_i^{b_i} (e^{gt+z_A} N_i)^{c_i} (e^{gt+z_A} L_i)^{1-b_i-c_i} \tag{2.112}$$

All markets must clear and this imposes additional restrictions on the model. Labor is not traded internationally, but some intermediate goods are. We allow exports for all intermediate goods and impose any relevant trade restrictions later in our simulations.

Clearing of the final goods market gives (2.12).

$$Y + (1-\delta)K = C + K' \tag{2.12}$$

Clearing in the factor markets gives equation (2.13) – (2.15).

$$K = \sum_i K_i \tag{2.13}$$

$$\overline{N} = \sum_i N_i \tag{2.14}$$

$$\overline{L_i} = L_i \tag{2.15}$$

International trade in intermediate goods gives equation (2.16).

$$Y_i = F_i + X_i \;\; \forall i \tag{2.16}$$

Here, X_i is exports of good i.

Balanced trade gives (2.17).

$$\sum_{i \in traded} p_i X_i = 0 \tag{2.17}$$

By Walras Law one of the equations in (2.12) – (2.17) is redundant. We choose to omit (2.17).

Mobility of capital and unskilled labor across sectors implies these factor prices must be identical across industries as in equations (2.18) and (2.19).

$$r_i = r \;\; \forall i \tag{2.18}$$

$$v_i = v \;\; \forall i \tag{2.19}$$

Traded goods are linked to foreign prices by (2.20a). This equation omits any tariffs, but this omission is unimportant since we use this only to calibrate the model and establish international prices consistent with observed trade patterns. We interpret these prices as being net of tariffs.

$$p_k = qp_k^*;\ k \in traded \tag{2.20a}$$

If a good is not traded then we use (2.20b) for that industry.

$$x_j = 0;\ j \in nontraded \tag{2.20b}$$

Finally, equations (2.21) and (2.22) specify the laws of motion for the two exogenous shock processes.

$$z_A' = \rho_A z_A + e_A';\ e_A' \sim iid(0, \sigma_A^2) \tag{2.21}$$

$$z_R' = \rho_R z_R + e_R';\ e_A' \sim iid(0, \sigma_R^2) \tag{2.22}$$

3. A Stationary Version

Equations (2.2), (2.4) – (2.6), (2.8) – (2.16) and (2.18) – (2.22) are a system of eighteen dynamic equations that define the system.

We can simplify the system by using (2.16) to eliminate the F_i's. We also define allocations of capital and unskilled labor over each of the I industries as shares of the totals and denote these shares as $\{\phi_i^K, \phi_i^N\}$. These replace the variables K_i and N_i. Finally, we define the export share in an intermediate industry as $x_i \equiv X_i / Y_i$ and replace the X_i's.

As specified, the system generates data that are non-stationary and our solution technique requires linear approximations of these equations about a steady state. Therefore, it is necessary to redefine variables in a way that renders the model stationary.

Equation (2.11) shows that technology is growing with a trend growth rate of g. Hence we can transform all growing variables ($K, \{v_i, w_i, Y_i\}_{i=1}^{I}, Y, C$) by dividing them by e^{gt}. We denote transformed variables by placing a carat over them.

This transformed system of equations is given by (3.1) – (3.16)

$$z_A' = \rho_A z_A + e_A';\ e_A' \sim iid(0, \sigma_A^2) \tag{3.1}$$

$$z_R' = \rho_R z_R + e_R';\ e_A' \sim iid(0, \sigma_R^2) \tag{3.2}$$

$$1 = \beta \mathrm{E}\{e^{z_R'} (\tfrac{\hat{C}'(1+g)}{\hat{C}})^{-\sigma} (1 + r' - \delta)\} \tag{3.3}$$

$$p_i \hat{Y}_i (1 - x_i) = a_i \hat{Y} \tag{3.4}$$

$$r_i \phi_i^K \hat{K} = b_i p_i \hat{Y}_i \tag{3.5}$$

$$\hat{v}_i \phi_i^N \overline{N} = c_i p_i \hat{Y}_i \tag{3.6}$$

$$\hat{w}_i \overline{L}_i = (1 - b_i - c_i) p_i \hat{Y}_i \tag{3.7}$$

$$\hat{Y}_i = (\phi_i^K \hat{K})^{b_i} (e^{z_A} \phi_i^N \overline{N})^{c_i} (e^{z_A} \overline{L}_i)^{1-b_i-c_i} \tag{3.8}$$

$$1 = \sum_i \phi_i^K \tag{3.9}$$

$$1 = \sum_i \phi_i^N \tag{3.10}$$

$$\hat{C} = \hat{Y} + (1-\delta)\hat{K} - (1+g)\hat{K}' \tag{3.11}$$

$$r_i = r \tag{3.12}$$

$$\hat{v}_i = \hat{v} \tag{3.13}$$

$$\hat{Y} = \sum_i p_i \hat{Y}_i \tag{3.14}$$

$$\prod_i \left(\frac{a_i}{p_i} \right)^{a_i} = 1 \tag{3.15}$$

$$x_j = 0;\ j \in nontraded \tag{3.16a}$$

$$p_k = q p_k^*;\ k \in traded \tag{3.16b}$$

4. Calibration and Steady States

Equations (3.1) – (3.16) are a stationary system, the steady state of which can be found by replacing the variables in these equations with their steady state values. Equations (3.9) – (3.16) are used as definitions. Equations (3.1) and (3.2) imply the steady state values of the shocks are zero. This reduces the system to (3.3) – (3.8); a system of fifteen equations in fifteen unknowns: $\overline{K}, \overline{q}, \{\overline{x}_j\}_{j \in traded}, \{\overline{p}_k\}_{k \in nontraded}, \{\overline{\phi}_i^K, \overline{\phi}_i^N\}_{i=1}^{I-1}$. This system might possibly be solved algebraically, but we choose to solve it numerically instead.

We need values for the following set of parameters: $\beta, \delta, \sigma, g, \{a_i, b_i, c_i, \overline{L}_i\}, \overline{N}, p^*_{k \in traded}$. We explain our choice of parameter values below.

δ is the depreciation rate and is set to 6.11%, the average of the observed ratio of depreciation reported by the IMF to a capital stock measure constructed by the perpetual inventory method from IMF real investment data. We use the period 1955 – 2003.

g is the annual growth rate of technology, which we set .512%, the average value of the Solow residual for 1986 – 2003.

g, β (the subjective discount factor) and σ (the intertemporal elasticity of substitution) are linked via the steady state version of equation (3.3), $1 = \beta(1+g)^{-\sigma}(1+\bar{r}-\delta)$. We set σ to 1 and choose a value for β of .986, which implies an annual real net return on capital equal to the ex post annual real return on government bonds between 1966 and 2008 of 1.876%.

The values for the sector shares in GDP (the a_i's) come from the GTAP6 database. We rely on the publicly available summaries of the database which aggregate industries into ten broad categories. We further aggregate these into five groups: agriculture, extraction, manufacturing, traded services, and non-traded services. We define the agriculture industry as any of the GTAP industries that use land as a factor of production. Similarly, extraction is any industry that uses natural resources. For these two industries only we modify our production function in equation (3.8) to include a fourth factor, which we interpret as either land or natural resources.

$$\hat{Y}_i = (\phi_i^K \hat{K})^{b_i} (e^{z_A} \phi_i^N \overline{N})^{c_i} (e^{z_A} \overline{T})^{d_i} (e^{z_A} \overline{L}_i)^{1-b_i-c_i-d_i} \tag{4.1}$$

We set the stock of land ($\overline{T}$) and natural resources ($\overline{R}$ replaces $\overline{T}$) both to 100 via normalization of units.

To obtain numerical values for the a_i's we take the ratio of total value-added on goods in that sector to total value-added on all goods.

We also calculate the b_i's, c_i's and d_i's, by taking the total compensation reported for each factor in that industry as a percentage of the value-added on the good.

For labor endowments we set the total endowment of labor to 100 by normalization. We obtain the relative amounts of unskilled labor and skilled labor by using data from the International Labor Organization and matching these to our five sectors as closely as possible.

To obtain international prices we use export shares for each of our industries as calculated from the GTAP data. We then solve for the steady state of our model using international prices as variables and export shares as long-run steady state values. When simulating our model we treat the prices of traded goods that we find this way as fixed parameters. The values of all parameters are reported for in table 1.

To determine which industries can be best classified as non-traded we sum the value of exports and imports and divide by value-added for that industry. If this number is less than 5%

we classify the industry as non-traded. By this criterion only one industry, non-traded services, is not a tradable good.

Table 2 reports the sensitivity of steady state values to changes in key parameters. The absolute size of the capital stock is quite sensitive to the choice of parameters. However, this size is an arbitrary normalization for any particular calibration. We therefore report ratios of variables that vary with this size. The table shows capital to output, consumption to output, and intermediate goods to final output measures. It also reports ratios of wages to output. Finally, it shows the linear approximation of the capital stock policy function (the value **P** discussed in section 5 below) which governs the dynamics of the model economy. The table shows the percent change in each of these as parameter values are adjusted away from their baseline values.

All wage ratios are remarkably stable regardless of the parameters chosen. The value of **P** is also fairly stable, ranging between .891 and .967, despite large variation in many different parameter values. With the exception of the agricultural industry, all intermediate goods ratios are also quite stable. K/Y, C/Y and Y_1/Y show marked changes when parameters change. K/Y is the most sensitive to changes. C/Y and Y_1/Y exhibit extreme changes only for very different values of β and δ, and even then all changes are less than 20%. All in all, the sensitivity analysis indicates the results we report below are not a spurious result of our choice of parameters.

We consider relaxation of immigration constraints by imagining policies that allow the labor endowment of the economy to rise by some fixed percent. We view foreign and domestic labor as perfect substitutes as long as the labor is of the same type. A policy maker can choose to relax or constrain immigration and alter the domestic supplies of labor. The policy maker can target particular types of labor, and leave endowments of the other types unchanged.

As figure 1 shows, the percentage of foreign residents to the total population is quite low in Japan compared to other developed countries. This number was 1.63% in 2006. By contrast, it was 11.71% for the United States in 2003 and 8.81% for Germany in 2006. We consider a change in immigration policy that raises the percentages from their current values to 9.50%. This is roughly the average of the US and Germany over the past 20 years. This corresponds to new immigration equal to 9.14% of the existing population. The policies we consider differ only in the mix of labor types allowed to immigrate.

1) We first consider a case where only unskilled labor is allowed to immigrate. This leads to an increase in the unskilled labor force of 11.15%.

2) Secondly, we consider a case where both skilled and unskilled labor are allowed to immigrate in the same proportions of the current labor force. This leads to an increase in all types of labor of 9.14%.

3) Third, we consider a case where both types of labor can immigrate, but skilled labor is given a priority. We allow equal numbers of workers of both types to enter the country, but since there are more unskilled workers in the workforce already, this leads to smaller percentage increases for unskilled labor. Unskilled labor rises by 5.57% and skilled labor rises by 25.44%.

4) A fourth scenario is to allow only skilled labor into a country. In this case, we increase all stocks of skilled labor by 50.88%.

5) For a fifth case we consider allowing skilled labor from only the non-traded services sector to immigrate. This is the sector that employs the most skilled labor and leads to an increase of L_5 by 86.03%.

6) Finally, we allow skilled labor from only the traded services sector (the second largest employer of skilled labor) to immigrate. This causes an increase in L_4 of 181.81%.

The steady state values for the baseline case and for the six different immigration cases are presented in table 3. Several interesting patterns emerge from these tables. First, increases in skilled immigration lead to greater increases in capital, output and consumption than increases in unskilled immigration. The ranking in terms of output increases from lowest to highest is: 1) unskilled only, 2) proportional, 3) equal, and 4) skilled only. This ordering corresponds to greater proportions of skilled labor in new immigration. Second, the highest gains in output and consumption come from targeting skilled labor in the traded services sector. Third, as the mix of immigration moves from unskilled to skilled labor, skilled wages fall and unskilled wages rise. Fourth, not surprisingly, increases in immigration of specific types of skilled labor lead to a drop in the wages for that labor. Fifth, an increase in nontraded services labor causes the wages of all other types of labor to rise, while an increase in traded services labor causes wages in agriculture, extraction, and manufacturing to fall.

In terms of welfare, we can measure consumption per capita and we find that this measure actually falls when unskilled workers only or proportional immigration is imposed. This would seem to validate the Japanese government policy of strong preferences for skilled immigration and restrictions on unskilled immigration. However, this drop comes from unskilled immigrants earning lower wages than average. Table 4 compares four measures of consumption. The first is the total consumption. The second is consumption per capita (x 100 for comparison purposes). Both of these are reported in Table 3 already. In addition, it reports the per capita consumption of new immigrants and the per capita consumption of preexisting workers (also x 100). Average consumption per capita falls in the first two cases because new immigrants have very low average consumption and this lowers the nationwide average. However, the average consumption of existing workers actually rises when these low wage workers immigrate.

These results indicate that, on average, existing workers would not be harmed, even by exclusively low skilled immigration. They also indicate, however, that the gains to all parties are greater when the mix of immigrants contains more skilled workers. The low average wages of unskilled immigrants may also be of some concern if low levels of consumption are correlated with social ills like crime, which are not modeled.

All these results are for the steady state, to which the economy will trend in the long-run. However, the long-run can be very far in the future and policy makers may well be interested in changes in output, consumption and wages along the transition path to this new steady state.

We now turn to these transition paths.

5. Model Dynamics

We use the method of undetermined coefficients to find linear approximations to the transition functions for the endogenous state variables in our model. Christiano (2002) and Uhlig (1999) discuss this method in detail.

We define three sets of variables from the system in equations (3.1) – (3.16). First are the exogenous state variables. We assign these to a vector $\mathbf{Z}_t$ as shown in (5.1).

$$\mathbf{Z}_t \equiv [z_A \quad z_R] \tag{5.1}$$

Similarly, we put the log deviations of the endogenous state variables from their steady state values into a vector $\mathbf{X}_t$. We denote log deviations of variable with a tilde. There is only one of these, and we alter the timing so that capital chosen for production next period is part of vector $\mathbf{X}$ now.

$$\mathbf{X}_t \equiv [\tilde{K}'] \tag{5.2}$$

We also define a set of endogenous non-state variables that cannot be easily solved as functions of the state variables. Uhlig (1999) refers to these as "jump" variables. We put these log-deviations into a vector $\mathbf{Y}_t$.

$$\mathbf{Y}_t \equiv [\tilde{q} \quad \tilde{x}_1 \quad \tilde{x}_2 \quad \tilde{x}_3 \quad \tilde{x}_4 \quad \tilde{p}_5 \quad \tilde{\phi}_1^K \quad \tilde{\phi}_2^K \quad \tilde{\phi}_3^K \quad \tilde{\phi}_4^K \quad \tilde{\phi}_1^N \quad \tilde{\phi}_2^N \quad \tilde{\phi}_3^N \quad \tilde{\phi}_4^N] \tag{5.3}$$

Lastly, we solve equations (3.4) – (3.11) & (3.14) to define a set of definition variables that are functions of the vectors $\mathbf{X}_{t-1}, \mathbf{X}_t, \mathbf{X}_{t+1}, \mathbf{Y}_t, \mathbf{Y}_{t+1}, \mathbf{Z}_t \;\&\; \mathbf{Z}_{t+1}$.

Using these definitions we can construct linear approximations of equations (3.12), (3.13), (3.15) & (3.16) of the form shown in equation (5.4).

$$\mathbf{AX}_t + \mathbf{BX}_{t-1} + \mathbf{CY}_t + \mathbf{DZ}_t = 0 \tag{5.4}$$

Similarly, an approximation of (3.3) yields equation (5.5).

$$\mathbf{FX}_{t+1} + \mathbf{GX}_t + \mathbf{HX}_{t-1} + \mathbf{JY}_{t+1} + \mathbf{KY}_t + \mathbf{LZ}_{t+1} + \mathbf{MZ}_t = 0 \tag{5.5}$$

Lastly, equations (3.1) & (3.2) can be written as equation (5.6).

$$\mathbf{Z}_{t+1} = \mathbf{NZ}_t + \boldsymbol{\varepsilon}_{t+1};\; \boldsymbol{\varepsilon}_{t+1} \sim iid(\mathbf{0}, \boldsymbol{\Sigma}) \tag{5.6}$$

The derivative matrices in equations (5.4) and (5.5) can be found algebraically, or they can be found using numerical methods.

Both Christiano (2002) and Uhlig (1999) show how this system can be solved for linear transition functions for the endogenous state variables and jump variables as expressed in (5.7) & (5.8).

$$\mathbf{X}_t = \mathbf{PX}_{t-1} + \mathbf{QZ}_t \tag{5.7}$$

$$\mathbf{Y}_t = \mathbf{RX}_{t-1} + \mathbf{SZ}_t \tag{5.8}$$

Given starting values for $\mathbf{X}_0$ and $\mathbf{Y}_0$, these two equations can be used in conjunction with (5.6) and a random number generator to simulate a series of deviations of variables from their steady state values over any arbitrarily long history. Once these deviations are known for every period we can recover the stationary values for each period using equation (5.9)

$$\hat{x}_t = \bar{x}e^{\tilde{x}_t} \tag{5.9}$$

Finally, we can construct non-stationary time-series for these variables by adding back the growth component that was removed earlier.

$$x_t = \hat{x}_t e^{gt} \tag{5.10}$$

To examine the transition of our model economy from the current steady state to a new one we set all exogenous shocks to zero to focus on the endogenous dynamics. We assume our economy is initially in the steady state, meaning that $\mathbf{X}_t = 0$. This will cause the economy to remain in the steady state until something changes. When policy is changed in period *T*, the economy will have a new steady. We set the value of $\mathbf{X}_t$ in this period to $\mathbf{X}_T = \ln(\overline{K}_{old} / \overline{K}_{new})$. From this point in time on, the economy will slowly converge to the new steady state, its dynamics driven by the **P** matrix in equation (5.7).

Figure 3 shows a typical transition; in this case for an increase of skilled immigration only. Notice that in addition to the long-run changes in steady state values, these transition paths show immediate effects. For example, the increase in skilled labor (which is assumed to happen immediately) causes immediate increases in output of all intermediate and final goods, as well as consumption. It also has immediate effects on exports and factor prices. After these immediate effects, the economy slowly transitions to a new steady state as the capital stock adjusts slowly over time. In some cases the upward jump is followed by additional increases over time; as in the case of outputs and consumption. In other cases, however, the initial jump overshoots the new steady state value and the variable returns partway (exports and skilled wages) or all the way back (the interest rate) to the original value.

We report only this one example because we are interested in augmenting these transition paths with confidence bands.

Transition paths like those above can be misleading because they show the effects of a change in steady state while assuming there are no exogenous shocks. Since the shocks are, on average, zero this is an unbiased prediction. However, it gives no sense of the amount of variation from this average one should expect. It is useful to have some sort of confidence band around these average predictions.

To do this we conduct a series of Monte Carlo simulations. We proceed as before, but generate non-zero series for $\boldsymbol{\varepsilon}_t$ using a random number generator. In our case we assume that the two elements of $\boldsymbol{\varepsilon}_t$ are distributed normally and independently from each other. The variance of each series is chosen to generate volatility of output that matches time-series data on real GDP. For each case we run 1000 Monte Carlo simulations and report the upper and lower 95% confidence bands for each time horizon from this set of simulations (blue dashed lines). We also report standard error bands by adding and subtracting two standard deviations at each time horizon (red dashed lines). These methods yield almost identical results.

Figure 4 examines the same case as figure 3. The difference is that we have added the deterministic trend back to all growing series and report the confidence and standard error bands. These graphs are the type of predictions a researchers would ideally provide to policy makers. That is, an average forecast of the likely effects of immigration reform, along with some feel for the uncertainty associated with these forecasts.

Figures 4 – 9 report transition paths under each of the six immigration policies discussed in section 5. These figures confirm many of the steady state results discussed in section 6. However, there are some additional findings worth mentioning.

First, there is a great deal of uncertainty surrounding the time paths of almost all the time series. Only export shares show changes that are significantly different from the previous steady state over the 40 years shown.

Second, for stationary time series, like export shares & the interest rate, the immediate adjustments to larger workforces are often much larger than the gradual adjustments to the new steady state that follow. For non-stationary series, the short-run jumps are much smaller in percentage terms because of the effects of long-run growth.

Third, regardless of the variable there is a great deal of inertia in the transition to the new steady state. Interest rates, for example, take more than twenty years to return close to their initial levels.

6. Conclusions

This paper has examined the effects of immigration liberalization in Japan. We have calibrated a DSGE model of a trading economy and considered the effects of six different policies which bring the percentage of the population that is foreign to roughly the same levels as are observed in Germany or the US. Because we have modeled growing economies, the immediate effects of increased immigration are relatively small compared to long-run increases due to economic growth. Effects on exports are much more dramatic in the short run. We have shown that immigration reforms which target skilled workers leads to greater welfare gains than those which allow in more unskilled labor. However, even with exclusively unskilled immigration, existing workers are made slightly better off on average when immigration restrictions are relaxed.

Table 1

Parameter Values

$\beta = .986 \quad \sigma = 1 \quad \delta = 6.110\% \quad g = 0.512\% \quad \overline{T} = \overline{R} = 100 \quad \overline{N} = 82.031$

Industry	industry share in output a_i's	capital share b_i's	unskilled labor share c_i's	land/ resources share d_i's	export shares x_i's	skilled labor endowment L_i's	int'l prices p_i's
Agriculture	0.012	0.310	0.502	0.180	-0.289	0.141	0.116
Extraction	0.005	0.378	0.297	0.279	-2.916	0.014	0.063
Manufacturing	0.203	0.399	0.381	n/a	0.203	2.157	0.449
Traded Services	0.402	0.355	0.390	n/a	-0.011	5.029	0.336
Non-traded Services	0.378	0.408	0.368	n/a	0	10.628	N/A

Table 2

Parameter Sensitivity of Baseline Model

$\beta = .986 \quad \sigma = 1 \quad \delta = 6.110\% \quad g = 0.\ 512\% \quad \overline{T} = \overline{R} = 100 \quad \overline{N} = 82.031$

	Baseline	**β= .95**	**β=.99**	**δ= 2.5%**	**δ= 10%**	**g=0**	**g= .25%**	**g= 1%**	**g= 2%**	**σ=.5**	**σ=2**	**σ=5**
K/Y	4.726	-32.4%	5.4%	81.3%	-32.6%	6.9%	3.4%	-5.8%	-15.8%	3.3%	-6.1%	-20.7%
C/Y	0.687	14.8%	-2.5%	8.0%	-3.2%	0.6%	0.3%	-0.5%	-1.4%	-1.5%	2.8%	9.4%
Y_1/Y	0.080	-7.4%	1.0%	12.4%	-7.4%	1.3%	0.7%	-1.2%	-3.3%	0.6%	-1.2%	-4.4%
Y_2/Y	0.020	5.4%	-0.7%	-7.7%	5.5%	-0.9%	-0.5%	0.8%	2.4%	-0.4%	0.9%	3.2%
Y_3/Y	0.548	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Y_4/Y	1.137	-0.6%	0.1%	0.9%	-0.6%	0.1%	0.1%	-0.1%	-0.3%	0.0%	-0.1%	-0.3%
Y_5/Y	1.348	0.8%	-0.1%	-1.2%	0.8%	-0.1%	-0.1%	0.1%	0.4%	-0.1%	0.1%	0.5%
100 w_1/Y	2.0054	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100 w_2/Y	3.3302	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100 w_3/Y	4.4302	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100 w_4/Y	2.6309	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100 w_5/Y	1.4511	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
v/Y	0.2830	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
P	0.926	0.900	0.929	0.960	0.891	0.930	0.928	0.922	0.914	0.897	0.947	0.967

Table 3

Steady State Values

	Baseline	Unskilled Only	Proportional	Equal	Skilled Only	L5 only	L4 only
U/capita	157.214	153.792	157.191	162.489	169.247	162.003	169.540
K	62.151	64.657	67.805	73.021	80.265	72.551	91.176
q	0.991	0.990	0.991	0.992	0.994	1.089	0.853
Y	13.150	13.681	14.347	15.451	16.984	15.348	19.246
C	9.034	9.399	9.857	10.615	11.669	10.544	13.208
C/capita	9.034	8.611	9.031	9.726	10.692	9.661	10.736
Y_1	1.049	1.049	1.109	1.211	1.361	1.155	0.891
Y_2	0.265	0.266	0.278	0.299	0.330	0.275	0.238
Y_3	7.206	7.459	7.866	8.547	9.511	7.631	4.599
Y_4	14.949	15.643	16.318	17.420	18.914	15.888	35.959
Y_5	17.725	18.414	19.342	20.885	23.039	24.172	20.264
x_1	-0.314	-0.368	-0.356	-0.335	-0.303	-0.267	-1.630
x_2	-2.969	-3.116	-3.117	-3.113	-3.095	-3.055	-6.512
x_3	0.150	0.145	0.151	0.160	0.172	0.148	-1.264
x_4	-0.079	-0.073	-0.078	-0.086	-0.097	-0.078	0.237
x_5	0	0	0	0	0	0	0
w_1	0.264	0.263	0.255	0.243	0.228	0.319	0.193
w_2	0.438	0.439	0.422	0.396	0.363	0.500	0.339
w_3	0.583	0.602	0.583	0.552	0.512	0.678	0.320
w_4	0.346	0.362	0.346	0.322	0.291	0.404	0.169
w_5	0.191	0.199	0.191	0.179	0.163	0.120	0.279
v	0.037	0.035	0.037	0.041	0.048	0.043	0.056
r	8.05%	8.05%	8.05%	8.05%	8.05%	8.05%	8.05%
t_1	0.000216	0.000216	0.000229	0.000250	0.000281	0.000262	0.000158
t_2	0.000046	0.000046	0.000049	0.000052	0.000058	0.000053	0.000036

t_1 is the return on land, t_2 is the return on natural resources

Table 4

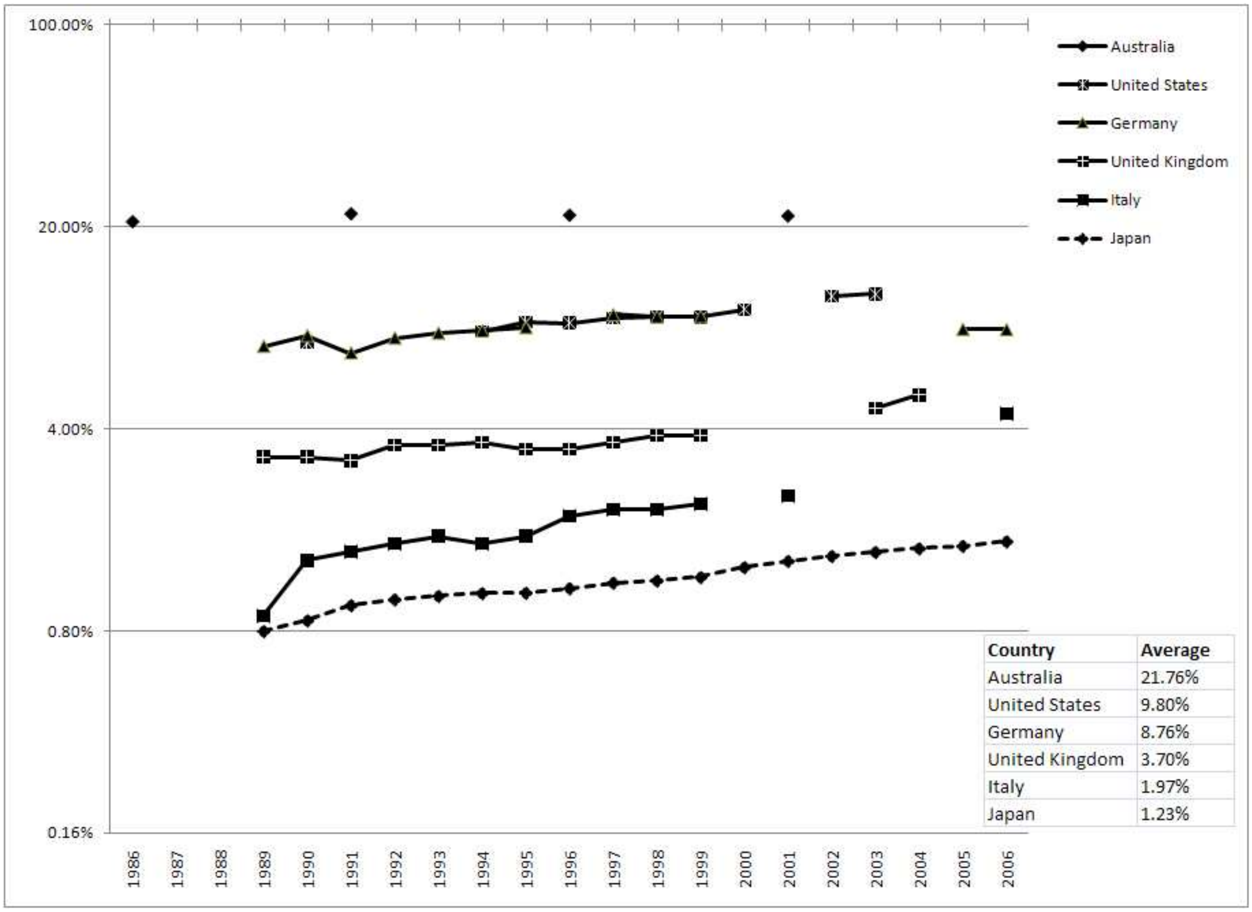
Steady State Consumption Comparisons

	Baseline	Unskilled Only	Proportional	Equal	Skilled Only	L5 only	L4 only
Total Consumption	9.034	9.399	9.857	10.615	11.669	10.544	11.717
Consumption per Capita	9.034	8.611	9.031	9.726	10.691	9.661	10.736
Consumption by New Immigrants	0.000	2.395	5.575	10.497	16.595	8.223	14.487
Consumption by Existing Residents	9.034	9.080	9.115	9.218	9.460	9.449	9.787

Figure 1

Foreign Population as a Percentage of the Total Population

(logarithmic scale)



Data from the International Labour Organization – LABORSTA database

Figure 2

Japan Migrant Population by Country of Origin 2006

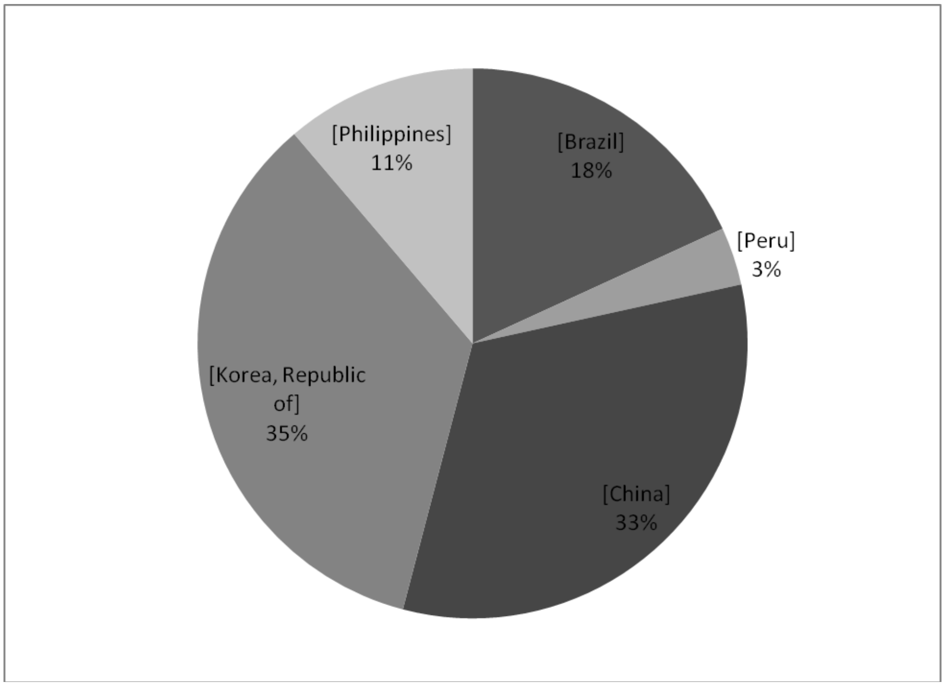


Figure 3

Transition Paths for an Increase in Unskilled Immigration Only

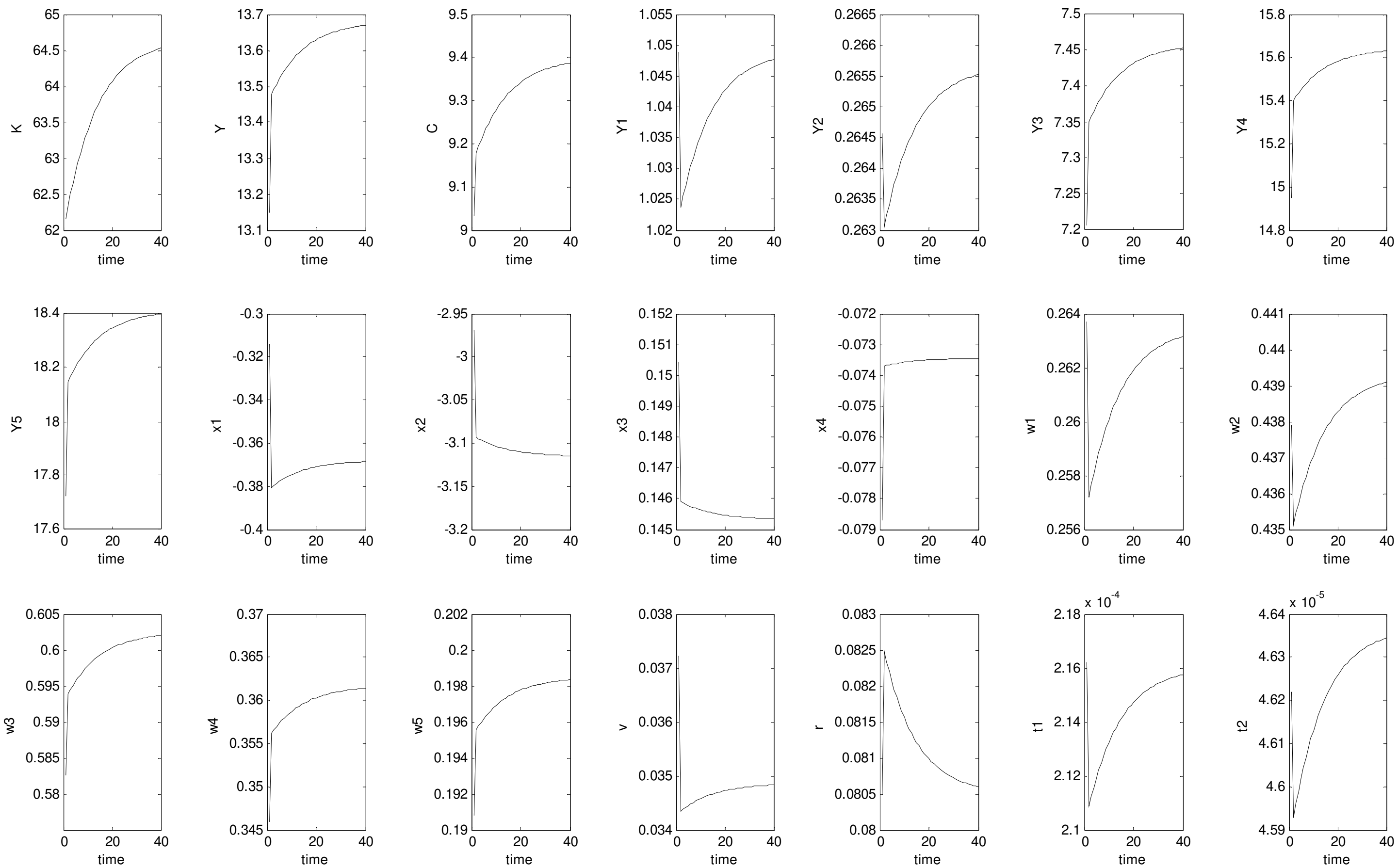


Figure 4

Transition Paths with Confidence Bands for an Increase in Unskilled Immigration Only

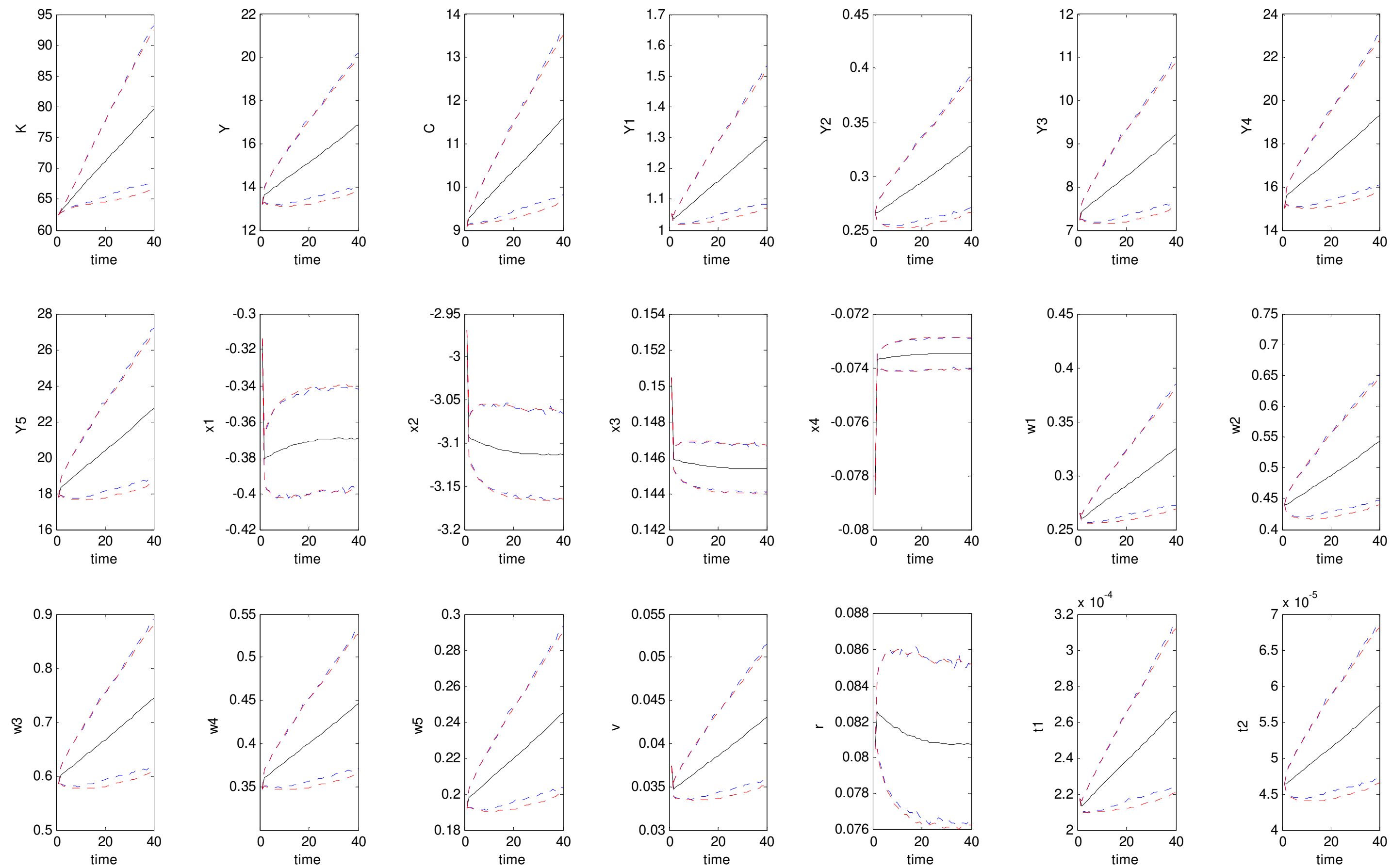


Figure 5

Transition Paths with Confidence Bands for a Proportional Increase in Skilled and Unskilled Immigration

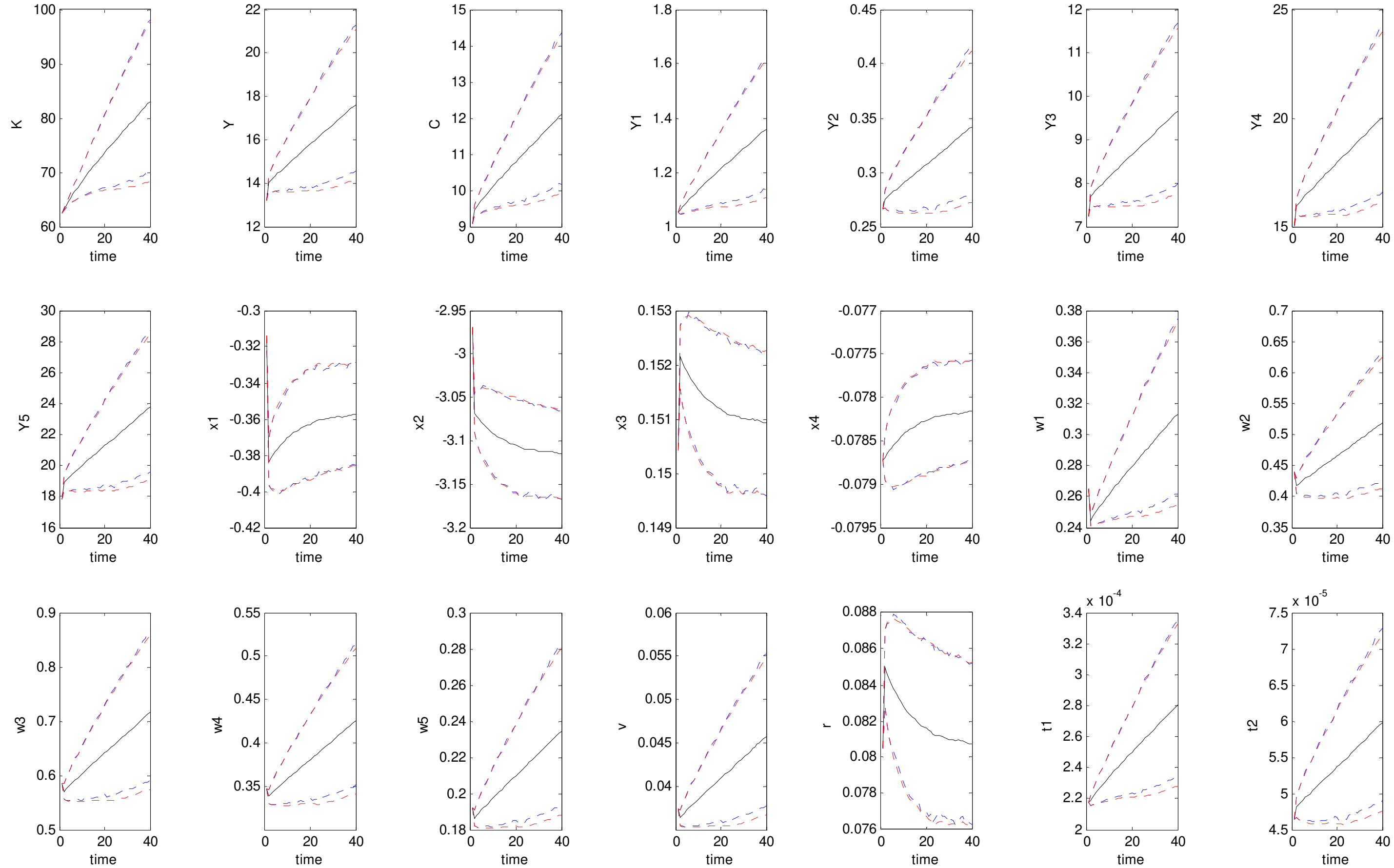


Figure 6

Transition Paths with Confidence Bands for an Equal Increase in Skilled and Unskilled Immigration

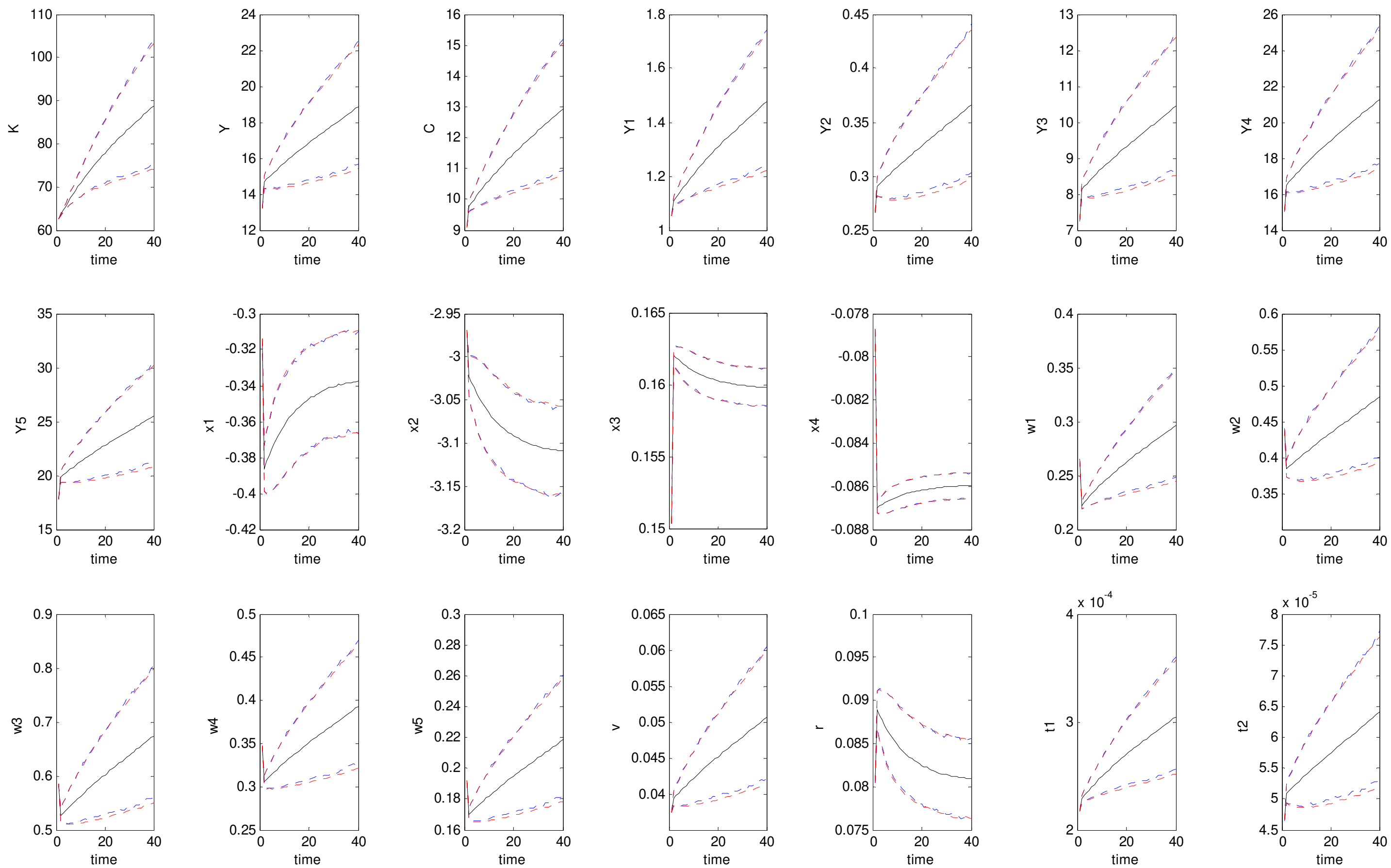


Figure 7

Transition Paths with Confidence Bands for an Increase in Skilled Immigration Only

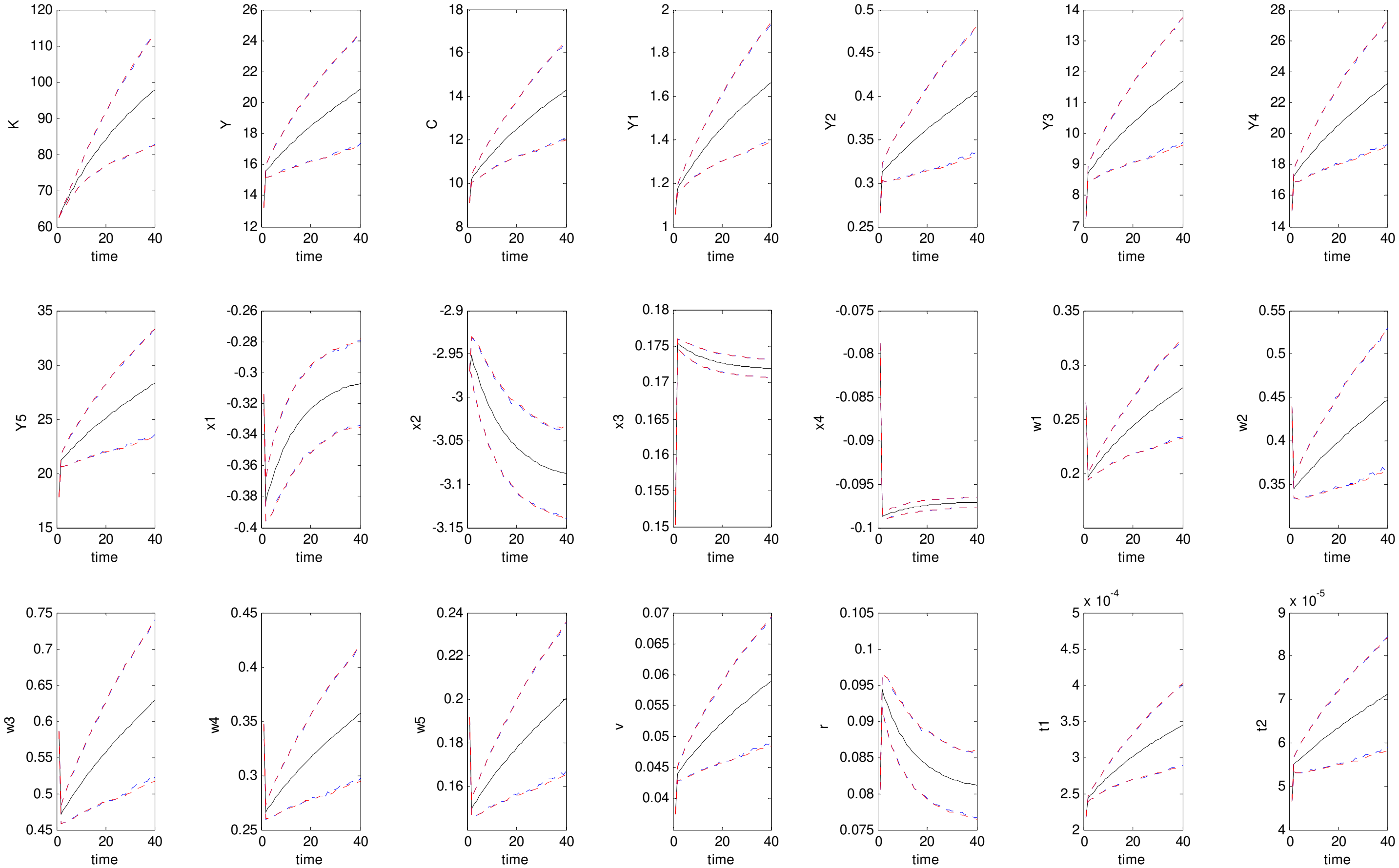


Figure 8

Transition Paths with Confidence Bands for an Increase in Skilled Immigration in Nontraded Services

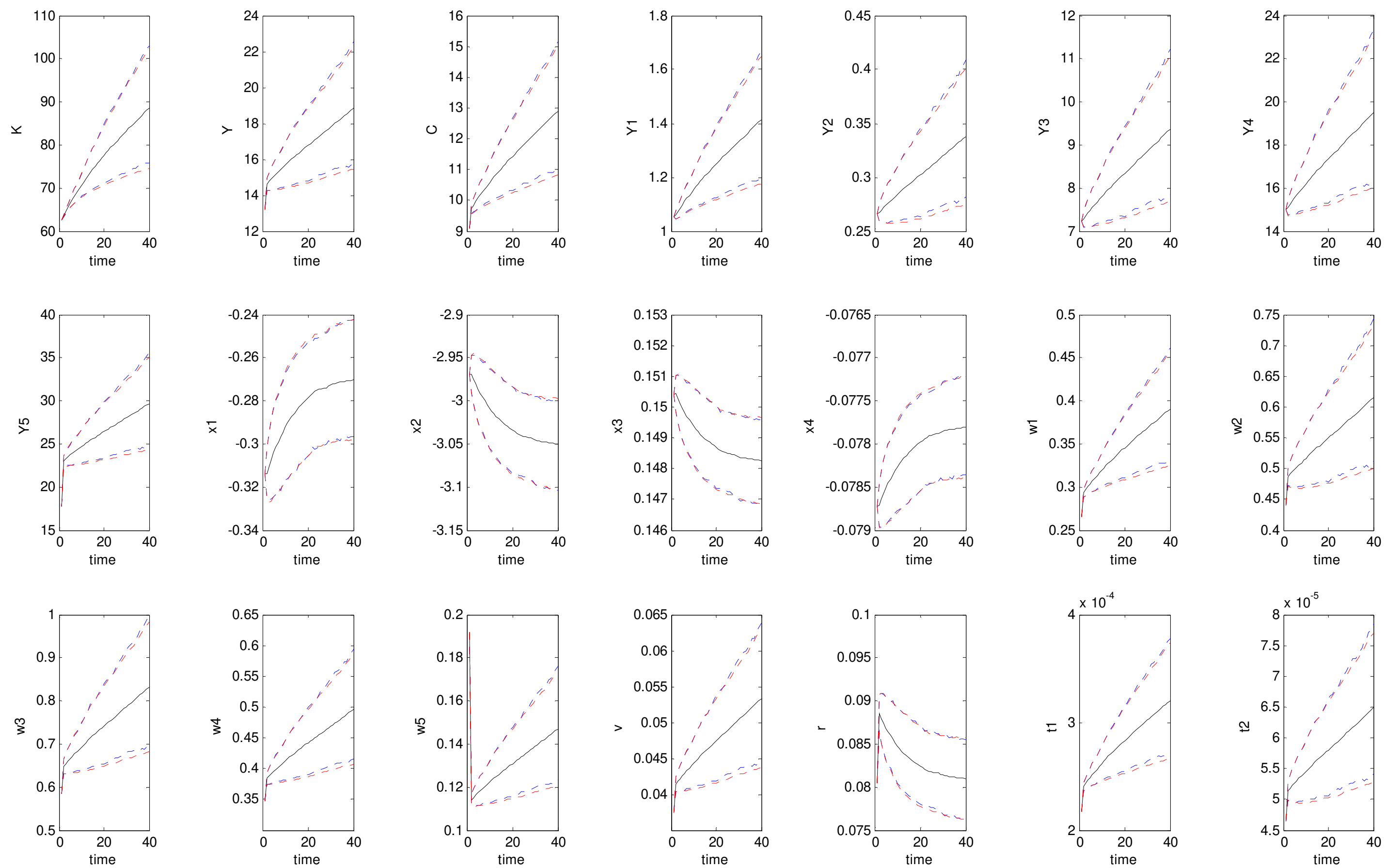
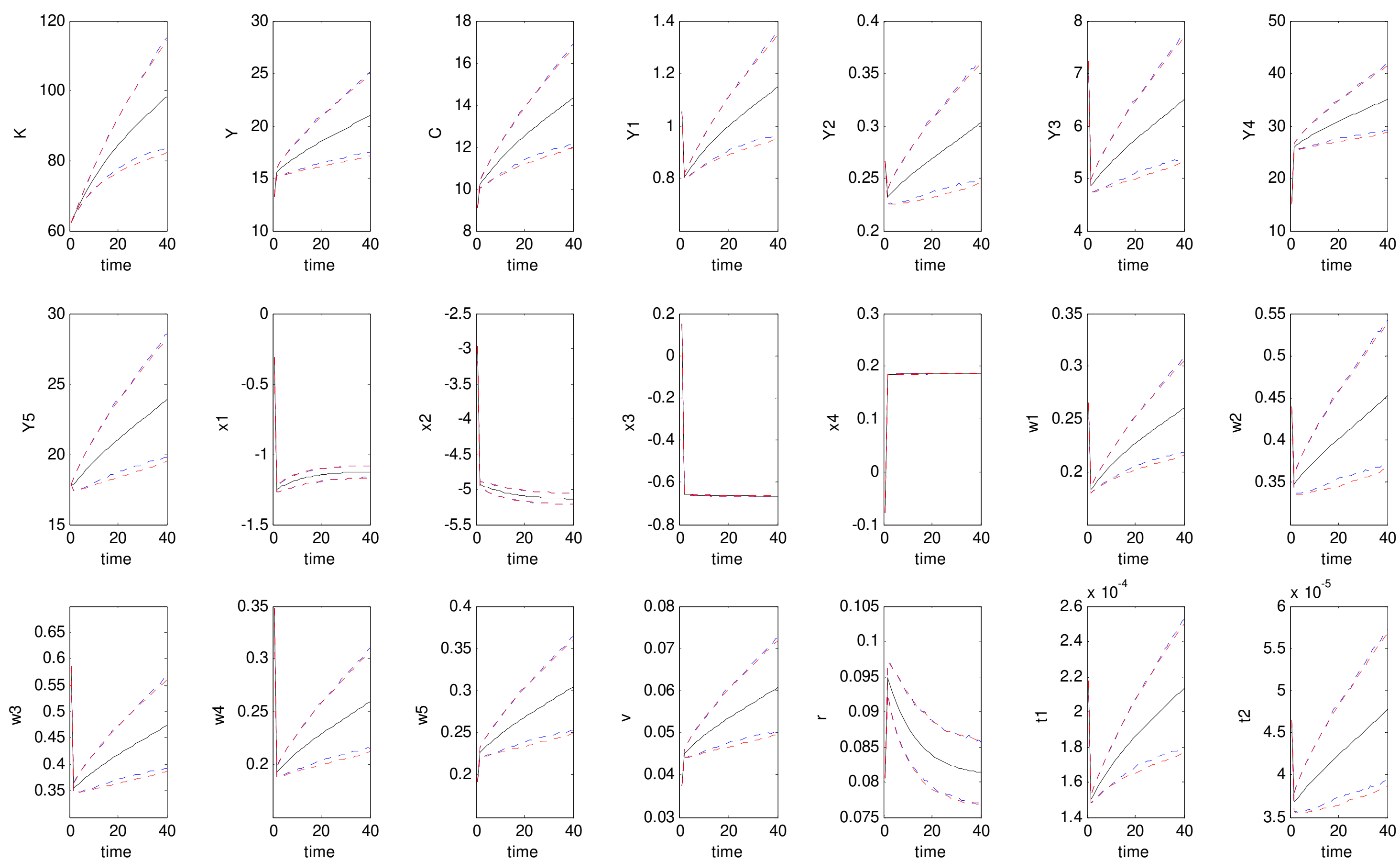


Figure 9

Transition Paths with Confidence Bands for an Increase in Skilled Immigration in Traded Services



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