Coming to America: Immigration and Labor Market Dynamics*

Preliminary and Incomplete

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January 17, 2017

Abstract

The impact of immigration on natives' employment opportunities has been the subject of intense debate in both the public and academic arena. On the academic front, much progress has been made in understanding how to appropriately estimate the historical impact of immigration. However, very little, if anything, has been done with regard to exploring the potential consequences of immigration reform. At the same time, although the literature points to possible margins of adjustment in response to an immigration shock, hardly any effort has been made to explicitly account for this or other possible margins of adjustment by workers, or to accommodate the fact that these adjustments are costly. In this paper, we directly confront these issues by presenting and estimating a structural dynamic general equilibrium model of the U.S. labor market in which heterogeneous natives and previous generation immigrants are able to make costly adjustments in response to immigration shocks by changing both their sector and occupation of employment, or by exiting the labor market all together. Deploying techniques from the discrete choice literature, we show how to tractably uncover these costs and other key parameters of the model. We then use the estimated model to simulate the labor market consequences of various immigration policy experiments. A bi-product is that we are also able to gauge potential biases in historical estimates of the impact of immigration associated with ignoring adjustments in workers' participation and both sectoral and occupational employment.

*We thank Jim Anderson, Jonathan Eaton, Ben Li, John McLaren, Andrés Rodríguez-Clare, Rosen Valchev and Stephen Yeaple for valuable discussions. All errors are, of course, our own.

1. Introduction

The effect of immigration on natives' labor market opportunities has been at the forefront of public discussion, and has also pre-occupied the minds of academic economists for some time now. Early "local" studies explored the implications of immigration on natives' wages by defining labor markets geographically and exploiting regional differences within a country (see, for instance, surveys by Borjas (1999) and Card (2005)), while later "national" studies defined labor markets as skill (education-experience) cells and used cross-skill variation as a means of identifying these effects (see, for example, Borjas (2003)).[1] Motivating the national approach is the idea that estimates derived in local studies may be downward biased because of firms or workers ability to make regional adjustments in response to immigration which may be fully accounted for at the national level, but not detectable at the local level (See Borjas (2003) and Aydemir and Borjas (2011)).[2] More recent work by Llull (2016) points to and quantifies the potential for selection bias in national studies associated with the rigidity of the typical assumptions of perfectly inelastic labor supply within skill categories, and country-level exogenous labor supply. In particular, relaxing these assumptions afford natives more flexibility in adjusting to immigration, thereby, potentially mitigating initial effects of immigration on natives' wages.

While the emphasis of this literature has been largely to appropriately estimate the historical wage and employment impact of immigration, little, if anything, has been done with regard to exploring the potential consequences of immigration reform (i.e., labor supply shocks associated with various immigration policy experiments). At the same time, although the literature points to possible margins of adjustment in response to an immigration shock, hardly any effort has been made to explicitly account for this or other possible margins of adjustment by workers, or to accommodate the fact that

[1]Both strands correlate changes in past immigration shares to changes in wage and unemployment levels. In particular, they examine the impact of immigration on the labor market at a specific point in time after the initial shock, for example, levels of wage and unemployment 5 years after the immigration shock. Moreover, once the labor market is defined, be it local or national, it is assumed to be *closed*, i.e., workers cannot make adjustments across different labor markets or exit the labor market all together. For example, in local studies this would mean workers cannot make regional adjustments, and in the case of national studies workers are not able to adjust across education-experience cells.

[2]While early work yielded mixed results (for example, Card (2001) finds evidence against, while Borjas (2006) finds evidence in favor of this margin of adjustment), the consensus regarding the results from this early literature appears to be that the evidence does not support internal migration by natives as an active margin of adjustment in response to immigration (See Peri and Sparber (2011) for a discussion of this). Recent work by Monras (2015), however, provides evidence indicating this margin of adjustment may be active.

these adjustments are costly. Directly confronting these adjustments and their associated costs is crucial for understanding the implications of immigration policy and it's overall implications for welfare. For instance, workers with heterogeneous skills may potentially respond to immigration by not only adjusting their level of participation (for example, exiting the labor market), but by also changing their sector or occupation of employment, or both. What are the transition costs faced by workers exposed to a particular immigration policy? How long will the labor market transition take? Will there be a lasting differential impact on workers' returns in the long run? What are the lifetime welfare effects on heterogeneous workers in different sectors and occupations, taking into account moving costs and transitional dynamics?

In this paper, we present and estimate a structural dynamic general equilibrium model of the U.S. labor market. We then use the estimated model to simulate the labor market consequences of various immigration reforms while accounting for endogenous labor force participation as well as *costly* sectoral and occupational adjustments by heterogeneous natives and previous generation immigrants. We explicitly map the short-to-medium term labor market transition in response to these policies, and measure the costs associated with this transition. This allows us to calculate the welfare gains and losses for different types of workers and for the economy as a whole.

While the primary focus of this paper is forward looking, (i.e., using policy experiments to assess the consequences of immigration reform), our framework also allows us to explore and guage potential biases inherent in historical estimates of immigration on natives' labor market outcomes assuming no labor market adjustments, as is standard in the literature. In particular, maintaining our definition of labor markets which includes sectoral and occupational dimensions, we estimate the parameters of the model using the typical static approach in which we do not account for labor market adjustments, and then compare these estimates to those obtained in our dynamic setting in which we do account for costly sectoral and occupational re-allocations. To get a sense of the importance of costly adjustment for welfare, we also compare our results with costly adjustment to the counterfactual with costless adjustment, i.e., perfect labor mobility.

Our framework builds on the dynamic rational expectations general equilibrium setting described in Artuc, Chaudhuri and McLaren (2010, henceforth ACM). The supply side extends the structure in ACM to accommodate immigrant and native workers, separately. Immigrant and native workers with heterogeneous skills are forward-looking and can change both sector and occupation of employment in each period, but must incur a cost to do so. Workers can also exit the workforce. Moving costs are type-specific and have both a common time-invariant part and time-varying idiosyncratic one indicating non-pecuniary motives for changing jobs (such as monotony, change in career direction, and so forth). On the demand side, workers from each occupation (blue-collar and white-collar) are combined with capital to produce a sectoral final good. In particular, we allow for capital-skill complementary by assuming a nested CES structure so that white-collar labor is combined with capital to form a CES aggregate which is then combined with blue-collar labor to form a CES aggregate sectoral good. Labor is defined in terms of skill (or efficiency) units with heterogeneous productivity depending on education, gender, and place of birth (or nativity).[3] The equilibrium then captures changes in natives' and previous generation immigrants' incentives to immigration induced supply shifts by way of changes in relative wages.

To estimate workers' dynamic discrete choice problem for the supply side of the model we exploit variation in different employment paths. Conditional on wages, individuals' frequency and pattern of sectoral and occupational movement yield important information about the costs and benefits of changing sectors and occupations as well as the magnitude of the shocks faced by workers. By assuming rational expectations, we are able to construct moments for estimation using realized continuation values in spite of the fact that workers make decisions based on previous expectations of the continuation values. Our estimation approach is analogous to the Euler equation one used by ACM and pioneered by Hotz and Miller (1993), but implemented in a setting with rich heterogeneity of worker types and mobility costs while at the same time accounting for both sectoral and occupational adjustments. In addition, our generalized extreme value distributional setting allows for correlation across employment options, thereby, accommodating the rejection of the independence of irrelevant alternatives (IIA), an assumption maintained in ACM and many other applications, and which implies proportional substitution across employment alternatives.[4] By relaxing the IIA limitation, we are effectively able to model labor supply decisions together with sector and occupation choices.[5] A methodologically appealing aspect of this approach is that we are able

[3]Note that this definition allows for imperfect substitution, albeit linear, among immigrant and native workers of otherwise identical types, thus, accommodating the finding in Peri and Sparber (2009) that immigrant and native workers of similar types and competing in the same labor markets often specialize in different tasks and so are not perfect substitutes.

[4]For other recent trade liberalization applications see, for example, Artuc and McLaren (2015), Caliendo *et al.* (2015) and Traiberman (2016).

[5]For instance, ACM and Artuc and McLaren (2015) only include working men in their sample and do

to effectively reduce the estimation to a series of linear regressions, thereby, circumventing the need to solve the model directly – which quickly becomes computationally cumbersome.

The model is fit to U.S. data from the Current Population Survey (CPS) for the period 1994 - 2014. In addition, we use data on sectoral capital stocks and on output from the Bureau of Economic Analysis (BEA). Using the estimated model, we conduct various counterfactual policy experiments. In particular, we investigate the short and long run labor market consequences of immigration policies that increase: the overall supply of immigrants; the supply of low-skill immigrants; the supply of high-skill immigrants; and the supply of immigrants in targeted industries (such policy can be thought of as increasing industry or academic-major specific immigration caps similar to the existing STEM H-1B policies). For each of the preceding policy experiments, we also examine their interaction with the speed of policy implementation (i.e., sudden vs gradual), and the degree of openness of the economy. In the benchmark model, we assume there is a non-traded service sector, a traded service sector, and a traded goods sector. We then experiment with closing all sectors so that all product market prices adjust to immigration-induced supply shifts; and with opening all sectors so that all product market prices are fixed.[6]

Our paper is closely related to the national approach pioneered by Borjas (2003) and further explored by Llull (2016), in that, we also abstract from regional variation. Llull (2016) extends the national framework to a Lee and Wolpin (2006) dynamic setting to explore the potential bias associated with ignoring education, occupation and participation as possible margins of adjustment on the traditional literature's estimates of historical wage and employment impact of immigration. We complement this work by presenting a streamlined dynamic rational expectations framework in which we move beyond historical assessments in order to explore the consequences of immigration reform. Our framework maintains many of the features in Llull (2016), but we also feature sectoral adjustments as a potential margin of adjustment. A consequence is that our setting also accommodates sector-product market feed-back effects in response to an immigration shock that are absent in a single good framework. Finally, our discrete choice setting is readily amenable to policy analysis, in that, it allows us to tractably estimate the structural parameters without solving workers' dynamic problem or specify-

not model the labor supply decision.

[6]For open sectors we make the usual small open economy assumption, i.e., that sector prices are fixed at some exogenous world price.

ing precisely what information workers have when forming their expectations of future wages. These estimated parameters can then be intuitively interpreted as reduced-form semi-elasticities, which by themselves are of independent interest.

Our paper is also related to a growing a strand of literature in international trade which explores the welfare implications of sectoral re-allocation from trade liberalization in a dynamic framework (see, for example, Artuc *et al.* (2010), DixCarneiro (2014) and Caliendo *et al.* (2015)). A new strand also features occupational re-allocations as an important margin of adjustments (see Artuc and McLaren (2015) and Traiberman (2016)). We instead explore the welfare consequences of immigration reform while at the same time accounting for both sectoral and occupational re-allocations by heterogeneous natives and immigrant workers.

The rest of the paper is organized as follows: Section 2 provides a description of the model; Section 3 describes the data; Section 4 outlines the estimation strategy and reports the parameter estimates; Section 5 reports the results of the counterfactual experiments; and Section 6 concludes.

2. A Dynamic Model of Immigration

The economy is composed of S productive formal sectors indexed $s \in \{1, \ldots, S\}$ and a nonproductive home sector denoted $s = 0$. Each productive sector produces output using capital, K, and two occupations of workers denoted $o \in \{B, W\}$ with B and W representing blue-collar and white-collar, respectively. There is a continuum of individuals of measure $\mathcal{N}$, who differ by: (i) gender denoted $g \in \{m, f\}$ with m and f represent male and female, respectively; (ii) origin of birth indexed $b \in \{N, F\}$ with N and F representing native and foreign, respectively; (iii) and education level indexed $e \in \{H, L\}$ with H and L denoting high and low education, respectively. Time is discrete.

In each period, an individual chooses whether to work, and if so, in which sector and occupation. Leaving the home sector or changing the sector or occupation of employment or both incurs a non-pecuniary mobility cost. Once the choice is made the momentary labor market is closed and competitive, and workers receive the marginal product of their labor. In our baseline model we assume that workers cannot change their educational status. However, we explore this margin of adjustment in an extension. Preferences are defined by a momentary utility function linear in consumption. Each individual maximizes the expected present discounted value of future flow utilities at a common discount rate $\beta \in (0,1)$. We start by characterizing the dynamic problem of an individual deciding where to move conditional on the path of real wages across time and across labor markets. Next we characterize the static sub-problem to solve for wages conditional on the supply of labor in a given market.

2.1. Employment Decisions And Labor supply

Individual Preferences

Individuals have preferences for different sectors and occupations. During each period, an individual also receives a random utility shock and can decide whether to move to a different sector (including the home sector) or occupation or both at the end of the period. Moving to a different sector or occupation or both incurs a non-pecuniary mobility cost. Let an individual of type $x \equiv (g,b,e)$ be a 3-tuple consisting of gender, nativity and skill, respectively, and denote $J = S \times 2$ as the dimension of productive sector-occupation pairs. To save on notation it is convenient to define the individual choice set in each period as $\mathbb{C} = \{0,\ldots,J\}$, where each $j \in \mathbb{C} \setminus \{0\}$ refers to a specific formal sector-occupation pair, and $j = 0$ denotes the home sector (i.e., $j \equiv (s,o)$, with $j = (0,o) = 0$ for all $o \in \{W,B\}$). When describing the demand side and the equilibrium of the model it will be useful to revert to explicitly considering sectors and occupation separately, i.e., using notation (s,o) instead of j.

We assume the flow utility of an individual of type x who is in sector-occupation j in time $t-1$ and decides to move to k in time t is given by

$$u_{x,t}^{j,k} = \eta_x^k - C_x^{j,k} + \epsilon_{x,t}^k + U\left(\mathbf{c}_t\right), \tag{1}$$

where η_x^k is the utility preference for sector-occupation k, $C_x^{j,k}$ is the cost for moving from sector-occupation j to sector-occupation k, $\epsilon_{x,t}^k$ is the idiosyncratic shock associated with sector-occupation k, and $U\left(\mathbf{c}_t\right)$ is the separable consumption portion of the utility:

$$U\left(\mathbf{c}_t\right) = \prod_{s=1}^{S} \left(c_t^s\right)^{\omega^s}, \tag{2}$$

where c_t^s denotes the sector good the individual consumes in period t, and $\sum_{s=1}^{S} \omega^s = 1$. Note that we abstract from savings and assume that agents consume their entire income within each period. As such, workers consumption allocation decisions are static and independent of their discrete time working allocation decision.

Consumption Allocation Problem

At any point in time an individual consumer working in sector-occupation s maximizes (2) subject to budget constraint:

$$\sum_{s=1}^{S} p_t^s c_t^s \leq W_{x,t}^j,$$

where p_t^i is the price of sector s's good, $W_{x,t}^j$ is the nominal wage in that sector, and we adopt the convention that $W_{x,t}^j = b$ for individuals in the home sector where b is a constant.

Denote $w_{x,t}^j$ as the real wage in sector s at time t for an individual of type x. We have $w_{x,t}^j \equiv W_{x,t}^j / P_t$, where $P_t = \tilde{\omega} \prod_{s=1}^{S} (p_t^s)^{\omega^s}$ is the standard Cobb-Douglas consumer price index which arises from the time t consumer optimization problem above, and $\tilde{\omega} \equiv \prod_{s=1}^{S} (\omega^s)^{-\omega^s}$ the constant. Note also that this specification implies momentary consumption, $U(\mathbf{c}_t)$, for an individual of type x is simply the real wage she receives in that period, i.e., $U(\mathbf{c}_t) = w_{x,t}^j$.

Working Allocation Problem

The time line for an individual's problem is as follows: at the beginning of each period t, an individual draws an idiosyncratic utility shock $\epsilon_t = \left(\epsilon_t^0, \ldots, \epsilon_t^J\right)$ and chooses her sector-occupation for t. If the individual was in sector-occupation j in time $t-1$ and decides to move to k in time t, as specified in (1), she receives flow utility $\eta_x^k + \epsilon_{x,t}^k - C_x^{j,k} + \overline{w}_{x,t}^k$, where $\overline{w}_{x,t}^k$ is her expected real wage in t, $\epsilon_{x,t}^k$ is her realized utility shock, η_x^k her utility preference for k and $C_x^{j,k} \geq 0$ is the cost of moving from sector-occupation j to sector-occupation k, such that the full cost of moving from j to k can be thought of as[7]

$$\epsilon_{x,t}^j - \epsilon_{x,t}^k + C_x^{j,k}.$$

We will be explicit about the structure of the non-idiosyncratic portion of moving costs (i.e., $C_x^{j,k}$) in what follows. In Subsection 4.1. we also specify the particular form of the

[7]We assume that at the time of decision making, individuals do not know their time t wages yet. An alternative assumption would be that individuals make decisions after observing $\mathbf{w}_{x,t} \equiv \left(w_{x,t}^1, \ldots, w_{x,t}^J\right)$, i.e., there is no idiosyncratic component in wage.

distribution of shocks.

Formally, let

$$\pi_{x,t}^{j,k} = \eta_x^k - C_x^{j,k} + \alpha \overline{w}_{x,t}^k, \tag{3}$$

where η^0 is normalized to 0, and α measures the importance of wage to utility relative to the variance of the idiosyncratic shock. Alternatively, α measures the importance of wages to the worker's discrete choice problem. A type x individual who is in sector-occupation j at the beginning of period t solves the following problem:

$$V_{x,t}^j(\epsilon) = \max_{k \in \mathbb{C}} \left\{ \pi_{x,t}^{j,k} + \epsilon_{x,t}^k + \beta \mathbb{E}_t \overline{V}_{x,t+1}^k \right\}, \tag{4}$$

where

$$\overline{V}_{x,t}^j \equiv \mathbb{E}_\epsilon \left[V_{x,t}^j(\epsilon) \right].$$

Switching Costs

We make the following assumption on type-specific mobility costs. First, we assume that the cost of not switching is 0 (i.e., $C_x^{j,j} = 0$ for all j), and the cost of switching to the home sector is 0, (i.e., $C_x^{j,0} = 0$ for all j). Secondly, we assume that the cost of switching from productive sector-occupation $j = (s, o)$, to productive sector-occupation $j' = (s', o')$ is given by

$$C_x^{j,j'} = c_{x,1}^{s,s'} + c_{x,2}^{o,o'} + c_{x,3} \mathbf{1}\{s \neq s'\} \mathbf{1}\{o \neq o'\}, \tag{5}$$

where $c_{x,1}^{s,s'}$ is the cost of switching sector (with $c_{x,1}^{s,s} = 0$), $c_{x,2}^{o,o'}$ is the cost of switching occupation (with $c_{x,2}^{o,o} = 0$), $c_{x,3}$ is an added cost of switching both sector and occupation, and $1\{s \neq s'\}$ and $\mathbf{1}\{o \neq o'\}$ are both indicator functions which take values one in the event of sectoral and occupational change, respectively, and zero otherwise. Notice that the latter allows for the possibility of sub- or super-additivity in the cost of joint switching. Finally, we assume that the cost of leaving the home sector is constant, i.e., $C_x^{0,j} = c_4$ for all $j > 0$.

2.2. Production And Labor Demand

Production Technology

Production is undertaken by sector-level representative firms with nested CES production functions. The output of sector $s \in \{1, \ldots, S\}$ is given by

$$Y_t^s = A_t^s \left\{ \alpha_1^s \left(\mathcal{L}_t^{s,B}\right)^{\rho_1^s} + (1-\alpha_1^s) \left[\alpha_2^s \left(\mathcal{L}_t^{s,W}\right)^{\rho_2^s} + (1-\alpha_2^s)\left(K_t^s\right)^{\rho_2^s} \right]^{\frac{\rho_1^s}{\rho_2^s}} \right\}^{\frac{1}{\rho_1^s}}, \tag{6}$$

where $\mathcal{L}_t^{s,B}$ and $\mathcal{L}_t^{s,W}$ denote respectively the aggregate skill units supplied by blue-collar and white-collar workers, and K_t^s is the aggregate physical capital employed in sector s. To allow for capital-skill complementarity, white-collar labor is combined with capital to form a CES aggregate. The elasticity of substitution between capital and white-collar labor is $1/\left(1-\rho_2^s\right)$ and that between the capital-white-collar composite and blue-collar labor is $1/\left(1-\rho_1^s\right)$. In particular,

$$\mathcal{L}_t^{s,o} = \sum_{b \in \{N,F\}} \mathcal{L}_{b,t}^{s,o} \tag{7}$$

with

$$\mathcal{L}_{b,t}^{s,o} = \int_{i \in \mathcal{N}_t^{s,o}} \ell_{x_i|b,t}^{s,o} \mathbf{1}\{b_i = b\},$$

where $\mathcal{L}_{b,t}^{s,o}$ is the aggregate skill units employed in sector s and occupation o coming from workers of nativity b at time t, $\ell_{x_i|b,t}^{s,o}$ are those for a particular worker i, $\mathcal{N}_t^{s,o}$ is the set of workers employed in sector s and occupation o in period t, and $\mathbf{1}\{b_i = b\}$ is the indicator function which takes value one when $b_i = b$ and zero otherwise. Note also that $\mathcal{N}_t^{s,o}$ satisfies $\sum_s \sum_o \mathcal{N}_t^{s,o} = \mathcal{N}$, i.e., the number of workers across sectors and occupations must add up to the total amount of workers.

Skill Production

An individual i of type $x_i = (g_i, b_i, e_i)$ with nativity $b_i = b$ employed in sector s and occupation o provides $\ell_{x_i|b}^{s,o}$ units of skill according to expression:

$$\ell^{s,o}_{x_i|b} = \exp\left\{\phi^{s,o}_{0,b} + \phi^{s,o}_{1,b}\mathbf{1}\{e_i = H\} + \phi^{s,o}_{2,b}\mathbf{1}\{g_i = f\} + \phi^{s,o}_{3,b}\mathbf{1}\{b = N\} + \phi^{s,o}_{4,b}\mathbf{1}\{e_i = H\}\mathbf{1}\{b = N\} + \phi^{s,o}_{5,b}\mathbf{1}\{g_i = f\}\mathbf{1}\{b = N\}\right\}, \quad (8)$$

where $b \in \{N, F\}$ is i's nativity, $e_i \in \{L, H\}$ denotes i's skill level, and $g_i \in \{m, f\}$ denotes i's gender, and $\mathbf{1}\{.\}$ is the usual indicator function. Note that the fourth and fifth expressions in equation (8) capture possible sub- or super-additive efficiency effects associated with being a highly educated native and a female native, respectively.[8]

2.3. Equilibrium

Labor Market Equilibrium

The labor market is competitive. Wages are determined in spot equilibrium. At time t a worker of type $x = (g, b, e)$ employed in sector s and occupation o receives wage

$$w^{s,o}_{x|N,t} = \frac{p^s_t}{P_t} r^{s,o}_t \ell^{s,o}_{x|N,t}, \quad (9)$$

or

$$w^{s,o}_{x|F,t} = \frac{p^s_t}{P_t} r^{s,o}_t \ell^{s,o}_{x|F,t} \quad (10)$$

if they are are native or immigrant, respectively, where $r^{s,o}_t \equiv \partial Y^s_t / \partial \mathcal{L}^{s,o}_t$ is the marginal product of labor in sector-occupation pair (s, o), $\ell^{s,o}_{x|b,t}$ is the measure of skill units provided by the worker conditional on nativity $b \in \{N, F\}$. Recall also that the aggregate supply of skills in sector-occupation (s, o) at moment t is given by equation (7). Hence, given sector prices p^s_t, the labor market equilibrium then entails real skill prices $r^{s,o}_t$ for all s and o such that labor markets clear.

Goods Market Equilibrium

At time t sector prices p^s_t must then satisfy sector clearing conditions:

$$p^s_t Y^s_t = \omega^s I_t$$

[8]In our estimation we find these interactions to be significant and so we include them in our specification of (8). An alternative, of course, would be to specify these interactions when outlining our estimation strategy.

where the left hand side is the value of sector s's output and the right hand side represents consumers' expenditure in that sector, ω^s is the Cobb-Douglas weight of sector s in consumers' preferences, and I_t is aggregate income (here we used the fact that in equilibrium aggregate expenditure must equal to aggregate income, i.e., $E_t \equiv \sum_{s=1}^{S} p_t^s Y_t^s = I_t$).

3. Data

The model is fit to the current population survey (CPS) from $1994 - 2014$. For our sample, we include civilians between the age of 25 and 64, excluding the military and farming population. A native person is defined as either a person born in the U.S. or one who was born to U.S. parents overseas. A person is considered high-skill if she has completed at least one year of college education. In addition, the Bureau of Economic Analysis (BEA) provides data on sectoral capital stocks and on output. We define sectors as follows: (1) Manufacturing, (2) Traded Services, (3) Non-traded Services. The home sector contains all of the rest, including home production, informal production, self-employed workers, unemployed workers, and others not in the labor force. In this section, we present some basic patterns of the data. We start by illustrating variation in average concentration of worker types across both sectors and occupations over the time period we consider. Next we show how this variation in sectoral and occupational shares changes across time. These observations provide motivation for our modeling choices made in the previous section. To be completed.

4. Estimation Strategy

In this section, we first describe the particular distributional form for the idiosyncratic shocks which allows us to tractably characterize the flows of workers across sector-occupation pairs (and home production) – a crucial step for estimating supply side parameters. Next we move to outline our strategy for estimating the key demand side parameters.

4.1. Estimating Supply Side

Idiosyncratic Shocks

We assume that the idiosyncratic shock for each sector-occupation pair j follows generalized extreme value distribution:

$$F(\epsilon) = \exp\left[-\exp\left(-\epsilon^0\right) - \left(\sum_{j\in\mathbb{C}\setminus\{0\}} \exp\left(-\epsilon^j/\nu\right)\right)^{\nu}\right] \tag{11}$$

where ν measures the degree of independence or correlation among ϵ^j for all productive sector-occupation pairs, i.e., $j \in \mathbb{C} \setminus \{0\}$.

Note that this is the familiar distributional assumption about workers' shocks used in nested logit models and which allows for the rejection of the independence of irrelevant alternatives (IIA) – a property maintained in ACM and similar settings (see, for example, Traiberman (2016) and Caliendo *et al.* (2015)), and which implies proportional substitution across alternatives. DixCarneiro (2014) and Lee and Wolpin (2006) both find that the variance of the unemployment option is significantly larger than those associated with employment ones, evidence suggesting a rejection of IIA across these options. In our generalized distributional form specified in (11) we allow for a rejection of IIA across home and productive sectors, and so effectively we are able to model labor supply decisions together with sector and occupation choices. In an extension we also explore different correlations across blue-collar and white-collar employment options.[9]

Sectoral and Occupational Flows

Before characterizing sectoral and occupational flows, first note that using the distributional form for the idiosyncratic shocks in (11) and taking expectation of equation (4) with respect to ϵ we have:

$$\overline{V}^j_{x,t}(\epsilon) \equiv \mathbb{E}_\epsilon\left[V^j_{x,t}(\epsilon)\right] = \ln\left[\exp\left(\pi^{j,0}_{x,t} + \beta\mathbb{E}_t\overline{V}^0_{x,t+1}\right) + \exp\left(\Omega^j_{x,t}\right)\right], \tag{12}$$

[9]Formally, let $\mathbb{C} = \mathbb{C}_B + \mathbb{C}_W$ such that $j \in \mathbb{C}_B$ and $j \in \mathbb{C}_W$ represent all sector-blue-collar pairs and sector-white-collar pairs, respectively. We then assume that the idiosyncratic shock for each sector-occupation pair j follows generalized extreme value distribution

$$F(\epsilon) = \exp\left[-\exp\left(-\epsilon^0\right) - \left(\sum_{j\in\mathbb{C}_B} \exp\left(-\epsilon^j/\nu_B\right)\right)^{\nu_B} - \left(\sum_{j\in\mathbb{C}_W}^{J} \exp\left(-\epsilon^j/\nu_W\right)\right)^{\nu_W}\right].$$

It is then evident for $\nu_B = \nu_W$ the expression above collapses to that in (11).

where

$$\Omega^{j}_{x,t}=\nu\ln\sum_{k=1}^{J}\exp\left\{\left(\pi^{j,k}_{x,t}+\beta\mathbb{E}_t\overline{V}^{k}_{x,t+1}\right)\Big/\nu\right\},$$

represents the value of working in period t for type-x individuals in state j, i.e., individuals who were in sector-occupation j in time $t-1$.

Let $\mu^{k,j}_{x,t}\equiv\Pr_{x,t}(k|j)$ be the probability at time t that workers of type x switches to sector-occupation k from sector-occupation j. It is straightforward to see that $\mu^{k,j}_{x,t}$ is also the share of type x workers in sector-occupation j at time t that chooses to move to sector-occupation k, i.e., gross flows of type x workers from j to k. We can then readily characterize sector-occupation flows by the following probabilities

$$\mu^{j,k}_{x,t}=\begin{cases}\exp\left(\pi^{j,0}_{x,t}+\beta\mathbb{E}_t\overline{V}^{0}_{x,t+1}-\overline{V}^{j}_{x,t}\right) & \text{for } k=0,\, j\in\mathbb{C}\\ \exp\left(\Omega^{j}_{x,t}-\overline{V}^{j}_{x,t}\right) & \text{for } k>0,\, j\in\mathbb{C}\\ \exp\left\{\frac{1}{\nu}\left(\pi^{j,k}_{x,t}+\beta\mathbb{E}_t\overline{V}^{k}_{x,t+1}-\Omega^{j}_{x,t}\right)\right\} & \text{for } j,k>0\\ \exp\left\{\frac{1}{\nu}\pi^{j,k}_{x,t}+\frac{\beta}{\nu}\mathbb{E}_t\overline{V}^{k}_{x,t+1}-\left(\frac{1}{\nu}-1\right)\Omega^{j}_{x,t}-\overline{V}^{j}_{x,t}\right\} & \text{for } k>0,\, j\in\mathbb{C}\end{cases}\tag{13}$$

where the first two expressions on the right hand side of equation (13), in descending order, represent the probabilities of being unemployed and working, respectively, the third is the probability of switching from productive sector-occupation j to productive sector-occupation k, and the fourth is the probability of switching from j to productive sector-occupation k.[10] Armed with equation (13) we now proceed to outline our estimation strategy.

Estimating Supply Side Parameters

First note that from equation (13) it follows that

$$\overline{V}^{k}_{x,t}-\overline{V}^{j}_{x,t}=\pi^{k,0}_{x,t}-\pi^{j,0}_{x,t}+\ln\mu^{j,0}_{x,t}-\ln\mu^{k,0}_{x,t},\tag{14}$$

and for each $k>0$ we have

$$\ln\mu^{j,k}_{x,t}-\ln\mu^{j,j}_{x,t}=\frac{1}{\nu}\left(\pi^{j,k}_{x,t}-\pi^{j,j}_{x,t}\right)+\frac{\beta}{\nu}\mathbb{E}_t\left[\overline{V}^{k}_{x,t+1}-\overline{V}^{j}_{x,t+1}\right].\tag{15}$$

Then for all $j\in\mathbb{C}$ and $k>0$, *rational expectations* together with (14) imply

[10]Note that this fourth expression follows from $\Pr_{x,t}(k|j),k>0=\Pr_{x,t}(k|j),j,k>0\times\Pr_{x,t}(k>0|j)$.

$$\mathbb{E}_t\left[\frac{\beta}{\nu}\left(\overline{V}^k_{x,t+1}-\overline{V}^j_{x,t+1}\right)\right]=\frac{\beta}{\nu}\left(\pi^{k,0}_{t+1}-\pi^{j,0}_{t+1}+\ln\mu^{j,0}_{x,t+1}-\ln\mu^{k,0}_{x,t+1}\right)+\xi^{j,k}_t \tag{16}$$

where $\xi^{j,k}_t$ is expectational error.

Substituting (16) into (15) implies for every $j\in\mathbb{C}$ and $k>0$ we have

$$\ln\mu^{j,k}_{x,t}-\ln\mu^{j,j}_{x,t}=\frac{1}{\nu}\left(\pi^{j,k}_{x,t}-\pi^{j,j}_{x,t}\right)+\frac{\beta}{\nu}\left(\pi^{k,0}_{t+1}-\pi^{j,0}_{t+1}+\ln\mu^{j,0}_{x,t+1}-\ln\mu^{k,0}_{x,t+1}\right)+\xi^{j,k}_t \tag{17}$$

Substituting (3) into (17), suppressing the type subscript x and rearranging yields the following regression for all $k\neq j$ such that $k>0$:

$$y^{j,k}_t=\phi^{j,k}+\widetilde{\eta}^k-\widetilde{\eta}^j+\frac{\alpha}{\nu}\left(\overline{w}^k_t-\overline{w}^j_t\right)+\frac{1}{\nu}z^{j,k}_{t+1}+\widetilde{\xi}^{j,k}_t \tag{18}$$

where

$$y^{j,k}_t\equiv\ln\widehat{\mu}^{j,k}_{x,t}-\ln\widehat{\mu}^{j,j}_{x,t},$$

$$z^{j,k}_t\equiv\ln\widehat{\mu}^{j,0}_{x,t+1}-\ln\widehat{\mu}^{k,0}_{x,t+1},$$

$\phi^{j,k}\equiv -C^{j,k}/\nu$ and $\widetilde{\eta}^j\equiv\eta^j/\nu$. Notice here that $\widetilde{\eta}^j$ is an origin fixed effect, $\widetilde{\eta}^k$ is a destination fixed effect, $\phi^{j,k}$ is the interaction term, and $\widetilde{\xi}^{j,k}_t$ represents a combination of expectational error and estimation error in $y^{j,k}_t$ and $z^{j,k}_t$. In particular, there are J fixed effects $(\widetilde{\eta}^1,\dots,\widetilde{\eta}^J)$,[11] and in each period, there are J^2 observations. Hence, the maximum number of independent interaction effects $\phi^{j,k}$ that can be estimated is $J\times(J-1)$. In particular, since (18) is estimated for $j\neq k, k>0$, $C^{j,j}$ and $C^{j,0}$ cannot be identified and have to be normalized.

Importantly, note that direct estimation of (18) can produce biased results, since fixed effects estimation requires strict exogeneity, i.e., $\mathbb{E}\left[\left(\overline{w}^k_t-\overline{w}^j_t\right)\widetilde{\xi}^{j,k}_{t'}\right]=0$ and $\mathbb{E}\left[z^{j,k}_{t+1}\widetilde{\xi}^{j,k}_{t'}\right]=0\forall t,t'$. By construction, the expectational error term $\widetilde{\xi}^{j,k}_t$ is mean-uncorrelated with any variables in the information set at the time of individual decision-making. However, strict exogeneity requires, for example, $\widetilde{\xi}^{j,k}_t$ to be uncorrelated with $\left(\overline{w}^k_{t+1}-\overline{w}^j_{t+1}\right)$ and $z^{j,k}_{t+1}$, which is clearly implausible.

To obtain consistent estimates of $\widehat{\alpha}$ and $\widehat{\nu}$ we proceed in two steps:

1. We take the first difference of equation (18) which is estimated using $(T-3)\times J^2$

[11] Corresponding to each combination of $j=1,\dots,J$, $k=1,\dots,J$, $j\neq k$ (recall that η^0 is normalized to 0).

observations, i.e., for each t, the dependent variables involve $z_{t+2}^{j,k}$, while $\overline{w}_{t-1}^{j}$ and $z_{t-1}^{j,k}$ are used as IVs. Hence equation (18) is estimated for $t = 2, \ldots, T-2$ using the following regression:

$$\Delta y_t^{j,k} = \frac{\alpha}{\nu} \Delta \left(\overline{w}_t^k - \overline{w}_t^j \right) + \frac{1}{\nu} \Delta z_{t+1}^{j,k} + \Delta \widetilde{\xi}_t^{j,k}, \tag{19}$$

where $\Delta x_t \equiv x_{t+1} - x_t$.

2. We use $\left(\overline{w}_{t-1}^k - \overline{w}_{t-1}^j \right)$ and $z_{t-1}^{j,k}$ as instruments for $\Delta \left(\overline{w}_t^k - \overline{w}_t^j \right)$ and $\Delta z_{t+1}^{j,k}$. Note that *rational expectations* imply $\mathbb{E}\left[\left(\overline{w}_{t-1}^k - \overline{w}_{t-1}^j \right) \Delta \widetilde{\xi}_t^{j,k} \right] = 0$ and $\mathbb{E}\left[z_{t-1}^{j,k} \Delta \widetilde{\xi}_t^{j,k} \right] = 0$.

4.2. Estimating Demand Side

In this subsection we outline our strategy for estimating the key production function parameters. It is convenient to explicitly use notation for sector and occupation separately, i.e, s and o instead of the joint sector-occupation index j. Let $r_t^{s,K} \equiv \partial K_t^s / \partial \mathcal{L}_t^{s,o}$ be the real return to capital in sector s and recall that the real return to labor in sector-occupation pair (s, o) is defined by $r_t^{s,o} = \partial Y_t^s / \partial \mathcal{L}_t^{s,o}$. Using (6) it is straightforward to derive key relations:

$$\log \frac{r_t^{s,W}}{r_t^{s,K}} = \log \frac{\alpha_2^s}{1-\alpha_2^s} + (\rho_2^s - 1) \log \frac{\mathcal{L}_t^{s,W}}{K_t^s} \tag{20}$$

and

$$\begin{aligned} \log \frac{r_t^{s,W}}{r_t^{s,B}} = {} & \log \alpha_2^s + \log \frac{(1-\alpha_1^s)}{\alpha_1^s} + \left[(\rho_2^s - 1) \log \left(\mathcal{L}_t^{s,W} \right) - (\rho_1^s - 1) \log \left(\mathcal{L}_t^{s,B} \right) \right] \\ & - \frac{\rho_1^s}{\rho_2^s} \log \left[\alpha_2^s \left(\mathcal{L}_t^{s,W} \right)^{\rho_2^s} + (1-\alpha_2^s) \left(K_t^s \right)^{\rho_2^s} \right] \\ & + \rho_2^s \log \left[\alpha_2^s \left(\mathcal{L}_t^{s,W} \right)^{\rho_2^s} + (1-\alpha_2^s) \left(K_t^s \right)^{\rho_2^s} \right] \end{aligned} \tag{21}$$

which form the basis of our approach for estimating demand parameters. We proceed in the following steps: first, we construct estimates $\mathcal{L}_t^{s,o}$ for each $o \in (B, W)$ using (7), (8), (9) and (10); second, we use estimates $\hat{\mathcal{L}}_t^{s,W}$ along with (20) to obtain estimates $\hat{\alpha}_2^s$ and $\hat{\rho}_2^s$; and finally, using estimates of $\hat{\mathcal{L}}_t^{s,o}$, $\hat{\alpha}_2^s$ and $\hat{\rho}_2^s$ together with (25) we obtain estimates of $\hat{\alpha}_1^s$ and $\hat{\rho}_1^s$.

For estimation purposes we make the following simplifying assumptions. We assume that for each s, sector product prices p_t^s are exogenous, and that sector-specific capital K_t^s is fixed. Without loss of generality, for each s, we set $p_t^s = 1$ and $K_t^s = 1$. Note that we only use these assumptions for estimation purposes. In our counterfactual exercises we allow for endogenous prices in non-traded sectors while maintaining the small country assumption for traded sectors, and we also consider the case of flexible capital. Finally, we normalize the mean wage of all workers to 1 in each year, i.e., we estimate the model using relative rather than absolute wages.

Step 1: Constructing Estimates of $\mathcal{L}_t^{s,o}$

Note that (8), (9), (10) together with our normalization of sector prices imply individual i of type $x_i = (g_i, b_i, e_i)$ with nativity $b_i = b$ employed in sector s and occupation o receives wages:

$$\begin{aligned} w_{x_i|b,t}^{s,o} = \exp\big\{&\lambda_{b,t}^{s,o} + \phi_{1,b}^{s,o}\mathbf{1}\{e_i = H\} + \phi_{2,b}^{s,o}\mathbf{1}\{g_i = f\} + \phi_{3,b}^{s,o}\mathbf{1}\{b = N\} \\ &+ \phi_{4,b}^{s,o}\mathbf{1}\{e_i = H\}\mathbf{1}\{b = N\} + \phi_{5,b}^{s,o}\mathbf{1}\{g_i = f\}\mathbf{1}\{b = N\}\big\} \end{aligned} \tag{22}$$

where $\lambda_{b,t}^{s,o} \equiv \ln\left[r_t^{s,o}\exp\left\{\phi_{0,b}^{s,o}\right\}\right]$. Note that since we cannot separately identify the nativity specific constant in skill production, $\phi_{0,b}^{s,o}$, we simply normalize it to zero, as is typically done.

Guided by equation (22), we then estimate the following Poisson regression for each (s, o) and $b \in \{N, F\}$:

$$\begin{aligned} \mathbb{E}\left[w_{x_i|b,t}^{s,o}\right] = \exp\big\{&\lambda_{b,t}^{s,o} + \phi_{1,b}^{s,o}\mathbf{1}\{e_i = H\} + \phi_{2,b}^{s,o}\mathbf{1}\{g_i = f\} + \phi_{3,b}^{s,o}\mathbf{1}\{b = N\} \\ &+ \phi_{4,b}^{s,o}\mathbf{1}\{e_i = H\}\mathbf{1}\{b = N\} + \phi_{5,b}^{s,o}\mathbf{1}\{g_i = f\}\mathbf{1}\{b = N\}\big\}, \end{aligned} \tag{23}$$

where, as mentioned above, $\lambda_{b,t}^{s,o}$ is a nativity-specific time effect. Using the estimates from (23) we can construct estimates of $\hat{\ell}_{x_i|b}^{s,o}$ using the normalized version of (8), and, in turn, we are able to construct estimates of $\hat{\mathcal{L}}_{b,t}^{s,o}$ and $\hat{\mathcal{L}}_t^{s,o}$ using (7).

Step 2: Estimating $\hat{\alpha}_2^s$ and $\hat{\rho}_2^s$

Using (20) along with estimates of $\hat{r}_t^{s,o}$ and $\hat{\mathcal{L}}_t^{s,W}$, and $K_t^s = 1, \forall s$, for each j we estimate

$$\log\frac{\hat{r}_t^{s,W}}{\hat{r}_t^{s,K}} = \log\frac{\alpha_2^s}{1-\alpha_2^s} + (\rho_2^s - 1)\log\hat{\mathcal{L}}_t^{s,W} + \zeta_t^s, \tag{24}$$

where $\zeta_t^{j,k}$ is the error term, to obtain estimates $\hat{\alpha}_2^s$ and $\hat{\rho}_2^s$.

Step 3: Estimating $\hat{\alpha}_1^s$ and $\hat{\rho}_1^s$

Finally, using $K_t^s = 1, \forall s$, estimates $\hat{r}_t^{s,o}$ and $\hat{\mathcal{L}}_t^{s,o}$ from Step 1, and estimates $\hat{\rho}_2^s$ and $\hat{\alpha}_2^s$ from Step 2 along equation (25) we estimate

$$\log \frac{\hat{r}_t^{s,W}}{\hat{r}_t^{s,B}} = \log \frac{(1-\alpha_1^s)}{\alpha_1^s} - (\rho_1^s - 1) \log \left(\hat{\mathcal{L}}_t^{s,B} \right) + \hat{\Phi}_{2,t}^{s,W} - \hat{\chi}_{2,t}^{s,W} + \nu_t^s \tag{25}$$

where

$$\hat{\Phi}_{2,t}^{s,W} \equiv \left[\log \hat{\alpha}_2^s + (\hat{\rho}_2^s - 1) \log \left(\hat{\mathcal{L}}_t^{s,W} \right) + \hat{\rho}_2^s \log \left(\hat{\alpha}_2^s \left(\hat{\mathcal{L}}_t^{s,W} \right)^{\hat{\rho}_2^s} + (1 - \hat{\alpha}_2^s) \right) \right],$$

$$\hat{\chi}_{2,t}^{s,W} \equiv \rho_1^s \log \left[\hat{\alpha}_2^s \left(\hat{\mathcal{L}}_t^{s,W} \right)^{\hat{\rho}_2^s} + (1 - \hat{\alpha}_2^s) \right]^{-\hat{\rho}_2^s}$$

and ν_t^s is the error term.

5. Counterfactual Experiments

To be completed.

6. Concluding Remarks

To be completed.

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