Financial Frictions and Occupational Mobility

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Abstract

We study the effects of financial market incompleteness on occupational mobility. Incomplete insurance not only generates an increase in consumption volatility, but also reduces occupational mobility. The correlation of labor supply with occupational productivity is lower than under complete markets. Low-asset workers remain in low-productivity occupations even when the expected value of switching is positive. Negative occupational productivity shocks therefore have larger effects on such workers' future earnings than they would for better insured workers. In a calibrated model, we find that the welfare costs of market incompleteness can be as large as 12 percent of lifetime consumption.

JEL: D31, D52, E21, J24

Keywords: occupational mobility, financial frictions, incomplete markets, self-insurance, welfare costs, training subsidies

1 Introduction

In the absence of complete markets, the nature of labor income risk is of fundamental importance for understanding the behavior of consumption and wealth in the cross-section and over time. A major source of labor income risk is occupation-level earnings shocks which are large and highly persistent, and therefore difficult for workers to insure against. Worse, market incompleteness potentially magnifies the effects of exogenous income shocks if it affects workers' ability to switch away from occupations hit by negative productivity shocks. In this paper we quantify the importance of financial frictions for occupational mobility and for welfare in a Bewley model. In our benchmark model mobility is 21 percent lower than in a comparable complete markets framework. The welfare costs of market incompleteness are very large: in our benchmark calibration, the average gain from moving to complete markets is 12.2 percent of lifetime consumption.

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We model occupational choice using an equilibrium search model in the style of Lucas and Prescott (1974), Alvarez and Veracierto (1999), and Kambourov and Manovskii (2009a). The returns to working in an occupation are stochastic, and occupational mobility is costly for three reasons: first, because workers must pay a retraining cost to change occupations, second, because of the opportunity cost of wages forgone while moving, and third, because a worker who starts work in a new occupation loses the occupation-specific human capital she had built up in her former occupation. Unlike the existing literature on occupational mobility, we do not assume that financial markets are complete. Instead, we follow the tradition of Bewley (1986), Huggett (1993), and Aiyagari (1994) and allow agents to self-insure by saving using a risk-free bond. This kind of insurance is only partial, because of the persistence of the shocks and because occupational mobility is undertaken precisely by those workers who have experienced negative shocks to their occupation, and hence, their earnings.

We calibrate the process for occupational-level earnings shocks to match information on U.S. occupational mobility from the Panel Study of Income Dynamics (PSID). Market incompleteness has substantial effects on occupational mobility. In the benchmark calibration of the incomplete markets model, 18.7 percent of workers move occupations each year, while under complete markets mobility increases to 23.7 percent. Reduced occupational mobility comes at a significant cost in terms of productivity, because more workers work in less productive occupations. Effective labor supply is 8.5 percent higher under complete markets. This is despite the fact that reduced occupational mobility under incomplete markets implies that agents both directly supply more labor and also accumulate more occupation-specific human capital: more precisely, total hours are 2.8 percent higher under incomplete markets than under complete markets, while 44.8 percent of agents are experienced in their occupations in the first case, compared with 39.8 percent in the second. The welfare cost of market incompleteness is also very large. As noted already, a randomly-chosen agent drawn from the incomplete markets economy would on average value the opportunity of trading thenceforth in complete insurance markets for her occupational labor productivity risk at 12.2 percent of her lifetime consumption. The welfare costs of incomplete markets mostly arise from greater consumption volatility, as expected in a Bewley model with highly persistent productivity shocks, but are significantly exacerbated by the worsening of occupational match quality just described.

Finally, we also consider the effects of more realistic policies which might increase occupational mobility. We consider the effect of subsidizing occupational mobility in a budget-neutral manner, paid for using a tax on labor income. Although this kind of policy increases occupational switching and leads to a better allocation of workers to productive occupations, there is an offsetting general equilibrium effect that reduces capital accumulation and wages, leaving the net welfare effect small.

Our paper contributes to several parts of macroeconomics and labor economics. There is a large literature establishing the importance of occupational mobility, in particular for job mobility (Miller, 1984; McCall, 1990) and for wages (Neal, 1995; Parent, 2000; Kambourov and Manovskii, 2009b). Our contribution is to show that incomplete markets are quantitatively relevant for under-

standing occupational mobility, and therefore also for understanding the cross-sectional distribution of occupational tenure, occupation-specific human capital, and wage dispersion. In our calibrated model, the standard deviation of log wages for full-time workers is 0.622 under incomplete markets, 11 percent greater than the corresponding complete markets value of 0.560.[1] Market incompleteness thus increases the level of cross-sectional wage dispersion implied by occupation-level productivity shocks, implying that these shocks are even more important than suggested by Kambourov and Manovskii (2009a).

Relative to the Bewley class of models, our paper adds a novel feedback mechanism from incomplete markets to the process for future labor income. In the benchmark model, agents' endowment of efficiency units of labor is subject to exogenous shocks, and market incompleteness means that agents' consumption also fluctuates. However, market incompleteness has no effect on the agent's future labor productivity. In our model, on the other hand, because occupational mobility is costly, negative shocks to an agent's labor productivity have different implications for rich and poor agents. Agents far from the lower bound on assets leave an occupation that receives negative shocks when doing so increases their permanent income. Agents near the lower bound, on the other hand, are unable to undertake the costly process of occupational mobility without an unacceptable reduction in their consumption, and so they endogenously end up with lower future labor income. This mechanism by which market incompleteness reduces the ability of some agents to undertake costly investment projects (such as occupational mobility) with positive net present value is closely related to work studying the effect of borrowing constraints on entrepreneurial choice (Evans and Jovanovic, 1989; Quadrini, 2000; Cagetti and De Nardi, 2006; Buera, 2009; Buera and Shin, 2011).[2]

There are a few papers which allow for workers to respond endogenously to the underlying shocks to their labor productivity in a Bewley model. Pijoan-Mas (2006), Marcet, Obiols-Homs, and Weil (2007), and Heathcote, Storesletten, and Violante (2008) allow for workers to make a static labor-leisure choice in response to fluctuations in their labor productivity and asset position. However, in these papers, there is no dynamic component to the labor supply choice made by workers, while in our model the choice to stop supplying labor in a worker's current occupation and undergo a costly reallocation to a new occupation has a dynamic effect on future labor productivity. Technically most closely related to our paper but substantially different in emphasis is the work of Krusell et al. (2008), who study a model which combines an islands model of search along the lines of Lucas and Prescott (1974) with incomplete markets as in the Bewley tradition. However, their focus is on understanding flows between employment and non-employment, and not on heterogeneity across different jobs or occupations. Our work is therefore complementary to theirs.

[1] We abstract for simplicity from other sources of wage dispersion, so that these measures of wage dispersion are smaller than their empirical counterparts. All agents in the model are ex ante identical, so we do not account for wage dispersion associated with education (Katz and Autor, 1999), gender (Goldin, 2006), other types of ex-ante heterogeneity, job search within occupations (Pavan, 2011), or other types of shocks.

[2] In an overlapping-generations setting, this mechanism could also be important for understanding choices made early in the life-cycle, such as educational choice or once-and-for-all occupational choice, as in Banerjee and Newman (1993) and Filmer and Pritchett (1999).

Finally, our paper is also related to the literature on misallocation in macroeconomics. An extensive literature on the dispersion of productivity across firms within the same industry suggests that misallocation of resources across firms within a narrowly-defined sector is very important for understanding aggregate productivity differences across countries and over time (Foster, Haltiwanger, and Krizan, 2001; Hsieh and Klenow, 2009). Our paper suggests that limitations on occupational mobility due to financial frictions are, while less important, still quantitatively significant for understanding the levels of labor and total factor productivity.

The structure of the remainder of the paper is as follows. In Section 2, we describe the model, including both our incomplete-markets benchmark and a version with complete markets. We describe our calibration strategy in Section 3. In Section 4, we report results, focusing on the comparison between complete and incomplete markets. Section 5 discusses the effect of subsidizing occupational mobility under incomplete markets, while Section 6 shows that the effects of market incompleteness can be greater for young agents, something that is particularly important given the higher frequency of occupational switching among the young. Section 7 concludes briefly.

2 Model

In this section we describe the economic environments that we consider. To simplify the exposition, we will describe only steady-state versions of these environments.

2.1 Preferences

There is a continuum of workers of fixed measure, normalized to one. Workers are infinitely-lived, and derive utility from consumption c. They discount the future with discount factor $\beta \in (0,1)$ (time is discrete). The felicity function is denoted $u(c)$, and the expected utility function is given by $\sum_{t=\tau}^{\infty} \beta^t u(c_t)$.

2.2 Occupations and Occupational Mobility

There is a continuum of islands, which we think of as representing occupations. Islands are indexed by $i \in [0,1]$. Each island i is characterized at any time t by an island-specific labor-augmenting productivity shock x_{it}, which takes values in a finite set $X \equiv \{x^1, x^2, \ldots, x^M\}$. x_{it} follows a first-order Markov process; write $f(x, x')$ for the probability that $x_{i,t+1} = x'$ conditional on $x_{it} = x$. We assume without loss of generality that the Markov process $f(\cdot)$ has a unique ergodic distribution with full support; this is without loss of generality because we focus on steady states. Denote the ergodic distribution by $\Psi(\cdot)$.

At the beginning of each period, a nonnegative measure of workers is located on each island. Workers can be either inexperienced or experienced in the occupation that is undertaken on island i. Workers who are experienced are more productive, so that their raw labor is $1 + \chi > 1$ times as productive as the labor of inexperienced workers.[3] The occupation productivity shock is labor-

[3] This simple way of modeling the return to occupational tenure follows Kambourov and Manovskii (2009a).

augmenting, so that on an island with productivity x, an inexperienced worker who works for fraction h of his endowment of time supplies xh efficiency units of labor, and an experienced worker who works for the same duration supplies $(1+\chi)xh$ efficiency units. Denoting experience by e, with inexperienced agents having $e = 0$ and experienced agents $e = 1$, a unified expression for this is that a worker with experience e supplies $(1+\chi)^e x$ efficiency units of labor per unit of time worked.

A worker who is inexperienced in the occupation associated with island i becomes experienced with probability $q \in [0, 1]$ each period that she remains and works on island i. The stochastic process of gaining experience conditional on remaining on an island is iid across workers, across islands, and over time. Define $\eta(e, e')$ to be the probability that next period's experience level will be e' conditional on today's experience e; then $\eta(0, 0) = 1 - q$, $\eta(0, 1) = q$, $\eta(1, 0) = 0$, and $\eta(1, 1) = 1$.

Each period, at the beginning of the period before supplying labor to a firm on this island, any worker has an opportunity to move islands. More precisely, the worker has the option to move to one specific alternative island i'. (We have in mind that the worker hears about from a personal contact network about the prospects in a particular occupation.) The worker does not have to take up the option, and if she ignores it, she remains on her current island and can supply labor as usual during the current period. Write $\Psi^m(\cdot)$ for the cdf of island productivity across the islands the agent might arrive on next period, and $\psi^m(\cdot)$ for the corresponding pdf. We assume that at the time of deciding whether or not to accept the mobility opportunity, the worker only knows the distribution $\Psi^m(\cdot)$ and not the realization of $x_{i',t+1}$.

Labor supply is inelastic at the intensive margin, but moving is time-consuming. Accordingly, a worker who remains on her island during the period supplies $\bar{h}_m$ units of raw labor, and a worker who undertakes an occupational switch supplies $\bar{h}_w$ units. (The reduction in labor supply for moving agents models the idea that it might take time for the worker to find a new job in her new occupation, the required time for retraining, and the possibility of lower wages during an 'apprenticeship' period.) In addition, a worker who moves pays a mobility cost $\kappa \geq 0$. At the beginning of the next period, the worker will be located on her new island. Because we assume that human capital is specific to each occupation, she will be inexperienced.

2.3 Production

There is a single representative firm which rents capital and labor and produces output.[4] If the firm rents k units of capital and l efficiency units of labor, its output is

$$Y(k, l) \equiv k^{\alpha} l^{1-\alpha},$$

[4] An alternative, equivalent, formulation would allow for a representative firm on each island, each producing the same final good. Provided capital is freely mobile across islands, each island's representative firm would set the same capital-efficiency units of labor ratio, so that aggregate output would be the same under this formulation.

units of the final good, where $\alpha \in (0,1)$. The firm is a price-taker in the rental market for capital. Capital is owned by workers, and rented each period to the firm. Capital depreciates at rate $\delta \in (0,1)$. The firm is also a price-taker in the rental market for labor. Labor supply to the firm from a given island i comes from aggregating the efficiency units of labor supplied by workers located on that island. The total labor supply to the firm then comes from integrating island-level labor supply over the measure 1 of islands.[5] Finally, the firm is also a price-taker in the final good market. We normalize the price of the final good to 1.

2.4 Incomplete markets model

In our benchmark model, we assume that there are incomplete markets, following Huggett (1993) and Aiyagari (1994). There are no state-contingent markets to insure either against the occupation productivity shock or the idiosyncratic experience shock. A worker holds assets a, which can never be lower than a lower bound $\underline{a}$, which can either be the natural borrowing limit or a strictly greater exogenous limit.

The state variables for an individual worker in the incomplete markets economy are the productivity of the island on which she is located, x, whether or not she is experienced in her island's occupation, e, and her assets, a. We write $e = 0$ for an inexperienced agent and $e = 1$ for an experienced agent. The Bellman value $V(x, e, a)$ of a worker who begins a period in state (x, e, a) satisfies

$$V(x, e, a) = \max\{V_w(x, e, a), V_m(a)\}$$

where $V_w(x, e, a)$ is the value of working on the current island, and $V_m(a)$ is the value of leaving

[5] Note that efficiency units of labor supplied on different islands are perfect substitutes. This assumption differs from that made by Kambourov and Manovskii (2009a), who assume imperfect substitutability. There are three reasons we make this modeling choice. First, the primitive shock process in our model is essentially to occupation-level wages, so that allowing for a finite elasticity of substitution between the goods produced on different islands should intuitively deliver similar results to ours—at least, as far as the decision problem of an individual agent is concerned—provided that one recalibrates the volatility of the island productivity process appropriately. Of course, this need not be true for the general equilibrium effects, but assuming that the elasticity of substitution between island-level output is high, for example, around 3 as suggested by both Kambourov and Manovskii (2009b) and Alvarez and Shimer (2011), in the latter case following the estimates in Broda and Weinstein (2006) for the elasticity of substitution, then the results we obtain should not differ too much from those that obtain under imperfect substitutability.

Second, if one regards the island-level shocks in our model as belonging not to the level of an occupation but of an occupation-worker match, perfect substitutability (that is, the absence of decreasing returns) is further justified since a worker's x shock turning bad might then reflect mostly on his own occupational match quality, rather than on occupational-level shocks. Assuming that an individual worker faces factor prices that are independent of her decisions, the substance of the perfect substitutes assumption, then seems natural.

Finally, our incomplete markets model is intractable if islands produce imperfectly substitutable goods. This is because the entire distribution of assets of agents on the island becomes a state variable for a given agent. In order to predict his own future wages conditional on staying on the island, he needs to predict the future price of the island's output, which in turn depends on the number of workers on the island, and then in turn on the mobility decisions of other agents, and so finally on their asset holdings.

the current island and moving to a new island. The value of working satisfies

$$V_w(x,e,a) = \max_{c,a'} u(c) + \beta \sum_{x'} \sum_{e'} V(x',e',a') f(x,x') \eta(e,e') \tag{1}$$

$$\text{s.t.} \qquad c + a' = (1+r)a + (1+\chi)^e x w \bar{h}_w$$

$$a' \geq \underline{a} \qquad \text{and} \qquad c \geq 0.$$

The value of moving is

$$V_m(x,e,a) = \max_{c,a'} u(c) + \beta \sum V(x',0,a') \psi^m(x') \tag{2}$$

$$\text{s.t.} \qquad c + a' = (1+r)a + (1+\chi)^e x w \bar{h}_m - \kappa$$

$$a' \geq \underline{a} \qquad \text{and} \qquad c \geq 0.$$

The worker takes as given the interest rate on assets r and the wage per efficiency unit of labor w. We write $g^a(x,e,a) = a'(x,e,a)$ for the savings policy of an agent in state (x,e,a), $g^c(x,e,a)$ for the consumption policy, and $m(x,e,a)$ for her mobility decision (setting $m(x,e,a) = 1$ if and only if the agent moves when she receives a mobility opportunity).

Because of the non-convexity introduced by the option to move islands, characterizing the solution to this problem analytically is not entirely straightforward.[6] We therefore use a numerical approach to understanding the model. In our simulations, when $\beta(1+r) < 1$ and $u(\cdot)$ has constant coefficient of relative risk aversion no less than 1, there is a unique solution for the value functions $V(\cdot)$, $V^w(\cdot)$, and $V^m(\cdot)$, as well as for the mobility policy $m(x,e,a)$ and the savings policy $g^a(\cdot)$. Moreover, there is $\bar{a} > \underline{a}$ such that for all (x,e,a) with $a \in [\underline{a}, \bar{a}]$, $g^a(x,e,a) \in [\underline{a}, \bar{a}]$.

Given the mobility and savings policies of agents, the process for individual state variables is Markov. If S is a Borel[7] subset of $Y = X \times \{0,1\} \times [\underline{a}, \bar{a}]$, write $P(x,e,a,S)$ for the probability

[6] If mobility were exogenous, the problem would reduce to a standard income fluctuations problem as in Huggett (1993) and Aiyagari (1994). In that environment, it can be shown as in Proposition 4 of Aiyagari (1993) that if $\beta(1+r) < 1$ and the coefficient of relative risk aversion is bounded above as $c \to \infty$, then there is a unique solution for the value functions $V(\cdot)$, $V^w(\cdot)$, and $V^m(\cdot)$ and for the savings policy $g^a(\cdot)$, and that there is an upper bound on assets. However, the introduction of endogenous mobility introduces a nonconvexity, which makes standard tools of dynamic programming inapplicable, and in particular, it is no longer true, for example, that $g^a(x,e,a)$ need be monotone in a. The issue is not that mobility is not chosen from a convex set—that could be handled in the usual way by allowing for lotteries over mobility—but that as in Buera (2007) and Vereshchagina and Hopenhayn (2009), the agent's value of assets depends on whether she moves occupation or not. This gives rise to a nonmonotonic savings policy as a function of current assets, and would also lead to a demand for lotteries over wealth. Given the quantitative goal of our paper, we do not allow for lotteries and we do not formally establish conditions under which the properties of the value and policy functions described in the main text hold.

[7] The topology on Y is the product of the discrete topologies on the two finite sets X and $\{0,1\}$ and the standard Euclidean topology on $[\underline{a}, \bar{a}]$.

that (x', e', a') lies in S, that is,

$$P(x,e,a,S) = \begin{cases} \sum\limits_{(x',e')|(x',e',g^a(x,e,a))\in S} f(x,x') & \text{if } m(x,e,a)=0 \\ \sum\limits_{x'|(x',0,g^a(x,e,a))\in S} \psi^m(x') & \text{if } m(x,e,a)=1. \end{cases}$$

Then given the probability measure μ for today's states (x, e, a), the probability measure for next period's states, μ', satisfies

$$\mu'(S) = \int_{X\times\{0,1\}\times[\underline{a},\bar{a}]} P(x,e,a,S)\, d\mu(x,e,a). \tag{3}$$

A *steady-state equilibrium under incomplete markets* is a set of functions $\{V(\cdot), V_w(\cdot), V_m(\cdot), g^a(\cdot), g^c(\cdot), m(\cdot)\}$, a measure μ, aggregate capital and labor K and L, and prices w and r such that

1. given the prices w and r, the functions $\{V(\cdot), V_w(\cdot), V_m(\cdot), g^a(\cdot), g^c(\cdot), m(\cdot)\}$ solve the household's decision problem;
2. prices equal marginal productivities, $w = Y_L(K, L)$ and $r = Y_K(K, L) - \delta$;
3. factor markets clear, $L = \int (1 - m(x, e, a))(1 + \chi)^e x\, d\mu(x, e, a)$ and $K = \int a\, d\mu(x, e, a)$; and
4. the measure μ is invariant, $\mu(S) = \int_{X\times\{0,1\}\times[\underline{a},\bar{a}]} P(x, e, a, S)\, d\mu(x, e, a)$.

Market clearing in the market for the produced good follows from Walras' law.[8]

2.5 Complete markets model

Under complete markets, the economic environment is unchanged from that described above, with the exception that we now allow for complete markets for both occupational productivity shocks and idiosyncratic shocks.

We implement complete markets using trade in Arrow securities. We assume that agents invest in Arrow securities which pay off in the following period conditional on the occupational productivity shock x' and experience level e' which will apply to the agent in that period. Denote by $b'(x', e')$ the number of units of the Arrow security corresponding to state (x', e') purchased by the agent in the current period; there is an Arrow security for each possible (joint) realization of (x', e'). Because the probability of state (x', e') depends on whether the agent works or moves during the current period, we assume that the markets for trading these Arrow securities $\{b'(x', e')\}$ open only after the agent has committed to her decision of whether or not to move occupations. This implies that the prices of the Arrow securities will depend on the agent's mobility choice. Denote by $q^w(x, e, x', e')$ the price of a security paying off in state (x', e') given that the agent's current

[8] To aid comparison, the form of the equilibrium definition is very similar to that in Pijoan-Mas (2006).

state is (x, e) and that she works on her current island, and by $q^m(x')$ the price of a security paying off in state $(x', 0)$ when the agent moves.

The agent enters the current period with a payment $b(x, e)$ from the Arrow security she invested in for the realized state (x, e) in the previous period. The agent's problem can be written

$$\tilde{V}(x, e, b) = \max\{\tilde{V}_w(x, e, b), \tilde{V}_m(b)\}$$

where $\tilde{V}_w(x, e, a)$ is the value of working and $\tilde{V}_m(x, e, b)$ is the value of leaving. These values in turn satisfy

$$\begin{aligned} \tilde{V}_w(x, e, b) &= \max_{c \geq 0, b'(\cdot)} u(c) + \beta \sum_{x'} \sum_{e'} \tilde{V}(x', e', b'(x', e')) f(x, x') \eta(e, e') \\ \text{s.t.} \qquad & c + \sum_{x', e'} q^w(x, e, x', e') b(x', e') = (1 + \chi)^e x w \bar{h}_w + b \end{aligned}$$

and

$$\begin{aligned} \tilde{V}_m(x, e, b) &= \max_{c \geq 0, b'(\cdot)} u(c) + \beta \sum_{x'} \tilde{V}(x', 0, b'(x', 0)) \psi^m(x') \\ \text{s.t.} \qquad & c + \sum_{x'} q^m(x') = (1 + \chi)^e x w \bar{h}_m - \kappa + b, \end{aligned}$$

where in each case we also impose the natural debt limit to prevent Ponzi schemes. Write the policy functions for the agent as $\tilde{m}(x, e)$, $c = \tilde{g}^c(x, e)$, and $b'(x', e') = \tilde{g}^b(x, e, b, x', e')$. Write $\Gamma(x, e, x', e')$ for the probability of state (x', e') next period conditional on the current state (x, e) and the mobility policy $\tilde{m}(\cdot)$; then

$$\Gamma(x, e, x', e') = \begin{cases} f(x, x')\eta(e, e') & \tilde{m}(x, e) = 0 \\ \psi^m(x)\mathbf{1}(e' = 0) & \tilde{m}(x, e) = 1 \end{cases}.$$

Also write

$$q(x, e, x', e') = \begin{cases} q^w(x, e, x', e') & \tilde{m}(x, e) = 0 \\ q^m(x') & \tilde{m}(x, e) = 1, \end{cases}$$

using the fact that a moving agent will not be experienced in the next period.

The Euler equation for an agent in state (x, e, b) is

$$u_c(c) = \beta \frac{\Gamma(x, e, x', e')}{q(x, e, x', e')} u_c(c')$$

When insurance markets are competitive, the no-arbitrage condition implies that

$$q^w(x, e, x', e') = \frac{1}{1 + r} f(x, x')\eta(e, e')$$

and

$$q^m(x') = \frac{1}{1+r}\psi^m(x').$$

Substituting into the agent's Euler equation gives that, as is standard under complete markets, independently of the realization of (x', e'),

$$u_c(c) = \beta(1+r)u_c(c').$$

This implies that $\beta(1+r) = 1$ is a necessary condition for a steady-state equilibrium (although we can consider the problem of an individual agent more generally; this will be useful in understanding the welfare gains associated with completing markets).

Finally, as under incomplete markets, we can define a law of motion $\tilde{P}(\cdot)$ so that for any $x \in X$, $e \in \{0,1\}$, $b \in \mathbf{R}$ and any Borel subset S of $X \times \{0,1\} \times \mathbf{R}$, $\tilde{P}(x, e, b, S)$ is the probability (x', e', b') lies in S. We also have an associated law of motion for the measure of agents over $X \times \{0,1\} \times \mathbf{R}$, defined analogously to (3) above.

A *steady state equilibrium under complete markets* is a set of functions $\{\tilde{V}(\cdot), \tilde{V}_w(\cdot), \tilde{V}_m(\cdot), \tilde{g}^b(\cdot), \tilde{g}^c(\cdot), \tilde{m}(\cdot)\}$, a measure $\tilde{\mu}$, aggregate capital and labor K and L, and prices w, r, $q^w(\cdot)$, and $q^m(\cdot)$ such that

1. given the prices w, r, $q^w(\cdot)$, and $q^m(\cdot)$, the functions $\{\tilde{V}(\cdot), \tilde{V}_w(\cdot), \tilde{V}_m(\cdot), \tilde{g}^b(\cdot), \tilde{g}^c(\cdot), \tilde{m}(\cdot)\}$ solve the household's decision problem;

2. prices equal marginal productivities, $w = Y_L(K, L)$ and $r = Y_K(K, L) - \delta$;

3. factor markets clear, $L = \int (1 - \tilde{m}(x, e, b))(1+\chi)^e x \, d\tilde{\mu}(x, e, b)$ and $K = \int b \, d\tilde{\mu}(x, e, b)$;

4. insurance is competitively priced, $q^w(x, e, x', e') = \frac{1}{1+r} f(x, x')\eta(e, e')$ and $q^m(x') = \frac{1}{1+r}\psi^m(x')$;

5. $\beta(1+r) = 1$; and

6. the measure μ is invariant, $\mu(S) = \int_{X \times \{0,1\} \times \mathbf{R}} \tilde{P}(x, e, b, S) \, d\mu(x, e, b)$.

Market clearing in the market for the produced good again follows from Walras' law.

Under complete markets, all agents choose mobility to maximize the expected present discounted value of labor income net of mobility costs. However, the distribution of consumption across agents is not uniquely characterized.

3 Model Parametrization and Calibration

In this section we describe the model parametrization and calibration procedure.

3.1 Parametrization

We assume that the model period is one year in order to minimize computational time, given the complicated nature of our model. In future work, we plan to recast the model at a quarterly

frequency. Utility is logarithmic, $u(c) = \log(c)$, to allow for a balanced growth path. In addition, no borrowing is allowed, $\underline{a} = 0$.[9]

An important assumption is on the distribution from which moving agents draw the productivity of their new island. One possible modeling assumption is to assume that occupational mobility is completely random, following Alvarez and Veracierto (1999). This models a situation where workers know nothing about their new island prior to making a switch. This would be appropriate if a worker's productivity in an occupation is an experience good, so that before starting work in the occupation, a worker has no information about her productivity there. It would also be appropriate if occupational productivity largely arises from the quality of the match between a worker and an occupation, rather from the characteristics of the occupation itself. An alternative would be to assume that occupational mobility is fully directed, following Lucas and Prescott (1974). In this case workers move only to occupations in which their productivity is high. This would be appropriate if a worker's occupational productivity largely arises from the characteristics of the occupation itself, rather than being match-specific.

In order to nest these two possibilities, along with intermediate cases, we allow for partially directed search, so that the next-period productivity $x_{i',t+1}$ of the destination island i' is drawn from the top $1-d$ quantiles of the ergodic distribution of island productivity shocks. That is, we set the distribution of destination islands for agents who move to be:

$$\Psi^m(\xi) = \begin{cases} \frac{\Psi(\xi)-c}{1-d} & \Psi(\xi) \geq 1-d; \\ 0 & \text{otherwise.} \end{cases} \tag{4}$$

This formulation nests the two extreme cases discussed above. If $d = 0$, then occupational mobility is fully random, while if $d = 1$ then occupational mobility is fully directed.

Finally, we assume that the first order Markov process for x approximates an AR(1) process of $\log(x)$:

$$\log(x') = \rho_x \log(x) + \epsilon_x \quad s.t. \;\; \epsilon_x \sim N(0, \sigma_x) \tag{5}$$

3.2 Calibration

The main structural parameters of our model are those governing the island productivity shock process ρ_x, σ_x; the returns to occupational experience χ, q; the financial cost of moving κ; and the frequency and directedness of mobility p, d. Following Kambourov and Manovskii (2009a) we calibrate ρ_x and σ_x so that the model can replicate the frequency and persistence of occupational mobility observed in the PSID for the 1970-73 period. Specifically, the model reproduces two targets: (1) an average annual rate of occupational mobility at the three-digit level of 15.9 percent; and (2) the average number of switches for those who switched occupations at least once over the

[9] We will investigate the robustness of the results to this assumption in a future version of this paper.

period, which is 1.59.[10] The model is not able to match these targets exactly; we generate an annual rate of occupational mobility of 18.7 percent and a mean of 1.81 occupational switches conditional on at least one switch. Also, similarly to Kambourov and Manovskii (2009a), we calibrate χ and q so that in the model it takes 10 years of occupational tenure to become experienced and earn a permanent wage increase of 20 percent, relative to inexperienced individuals.

To calibrate the financial cost of moving κ we follow evidence from Heckman, Lalonde, and Smith (1999). They report that the average vocational training program in the US takes about three months of study and has a direct cost of \$2,000 to \$3,000 in 1997 U.S. dollars. Kambourov and Manovskii (2009a) argue that this monetary cost is close to two months of wages for the median worker in 1997. We take a slightly different approach and set the mobility cost to two months of wages for the mean worker in our model. Unreported robustness exercises show that our main results are robust to modest changes in the mobility cost. Note, however, that casting the model at an annual frequency exaggerates the indirect (time away from work) cost of moving.

A key parameter of the model is d, which governs the directedness of search. Neither of the two extreme assumptions $d = 0$ and $d = 1$ seems empirically reasonable. Given our production structure, fully directed search would mean that there is no wage dispersion among workers conditional on switching occupations. Moreover, the OLS return to occupational tenure would be substantially more negative than the true return to tenure, because workers would move only to occupations with maximal productivity, which would then revert to the mean. However, using an empirical strategy pioneered by Altonji and Shakotko (1987), Kambourov and Manovskii (2009b) find that the OLS returns to tenure are in fact upward-biased. Alternatively, fully random search means that we would see many workers experience substantial wage cuts upon switching occupations. Mobility into declining occupations would be equally likely as mobility into growing occupations, contrary to evidence reported by Şahin et al. (2011). Finally, repeated occupational switches would be common as workers unlucky enough to switch into a low-productivity occupation would immediately move again; this is at odds with observations on repeat mobility in the PSID. In future work, we plan to calibrate the parameter d by using the joint distribution of these variables. In the current version of the paper we simply set d at an intermediate value of 0.5 to allow for partially-directed search.

Following Chang and Kim (2006), we assume that when working individuals supply $\bar{h}_w = 1/3$ of their time. We also assume that individuals who choose to move can still work a fraction $\bar{h}_m = 1/6$ of their time. It is convenient to assume that this labor is supplied in the old occupation. Allowing for the three months duration of the typical training program (Heckman, Lalonde, and Smith, 1999), this calibration implies that a moving individual supplies labor with an intensity two-thirds as much as for a worker who does not switch occupations during the remainder of the year. We think of this lower effective labor supply as modeling some combination of time spent physically moving locations, in job search, or in learning about the potential occupational match.

Last, we set α, β, and δ following standard practices in the literature. We calibrate the capital

[10] Because both ρ_x and σ_x affect these targets, we use a Simulated Method of Moments (SMM) approach whereby the sum of squared deviations between model-simulated and data moments is minimized.

Parameter	Target	Value
α	Capital income share	0.36
δ	Annual depreciation rate	0.08
β	Annual real interest rate $r = 0.04$	0.933
ρ_x, σ_x	3-digit annual occupational mobility and average number of switches for those who switched occupations at least once in a 4-year period	0.945, 0.350
κ	Two months of forgone wages for mean worker	0.478
χ, q	Return to 10 years of of occupational experience	0.2, 0.1

Table 1. Calibration targets and parameter values

income share α to 0.36 and the annual depreciation rate δ to 8 percent. Following Chang and Kim (2006), we calibrate β so that in equilibrium the annual real interest rate is 4 percent. Table 1 summarizes the calibration targets and parameter values.

4 Results

In this section we present our results on the effects of market incompleteness on occupational mobility, occupational tenure, and welfare. We do this by presenting comparisons between complete and incomplete markets economies.

4.1 Occupational Mobility Policies

We begin by describing the policy functions for occupational mobility under the two market environments. Figure 1 depicts the mobility policies in the incomplete markets model graphically. The left panel of the figure shows the mobility policy $m(x, 0, a)$ for inexperienced agents; the right panel shows the corresponding policy $m(x, 1, a)$ for experienced agents. On the horizontal axis of each graph are assets a (in absolute units); the mobility policies for different x values are shown using different line styles. Recall that $m(x, e, a)$ takes values of either zero or one. The graphs show that mobility is increasing in assets. For the lowest island productivity x^1, agents with the ability to pay the mobility cost (that is, with $a > \kappa$) almost all choose to move. For a higher island productivity x^8, the asset threshold at which agents switch occupations increases. Agents with

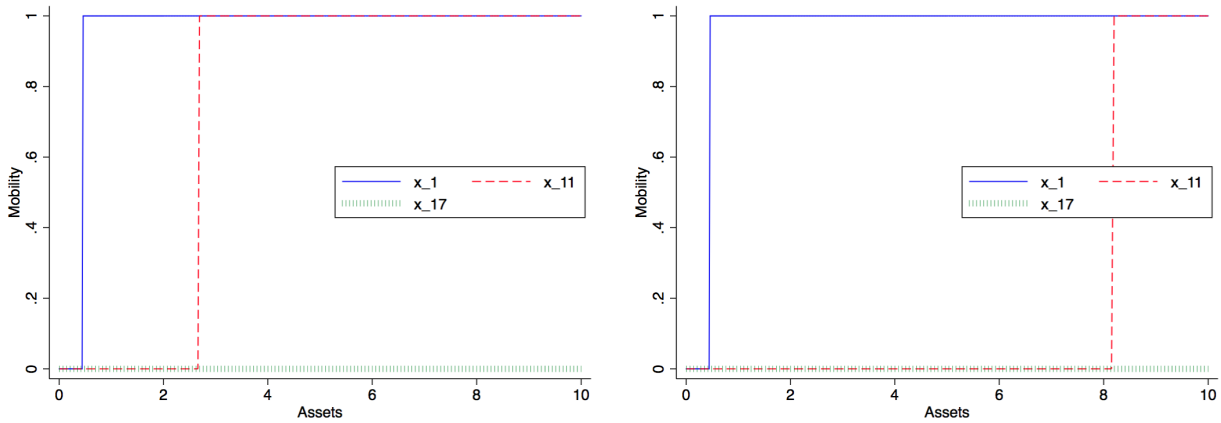

Figure 1. Mobility policies for inexperienced (left) and experienced individuals (right), incomplete markets.

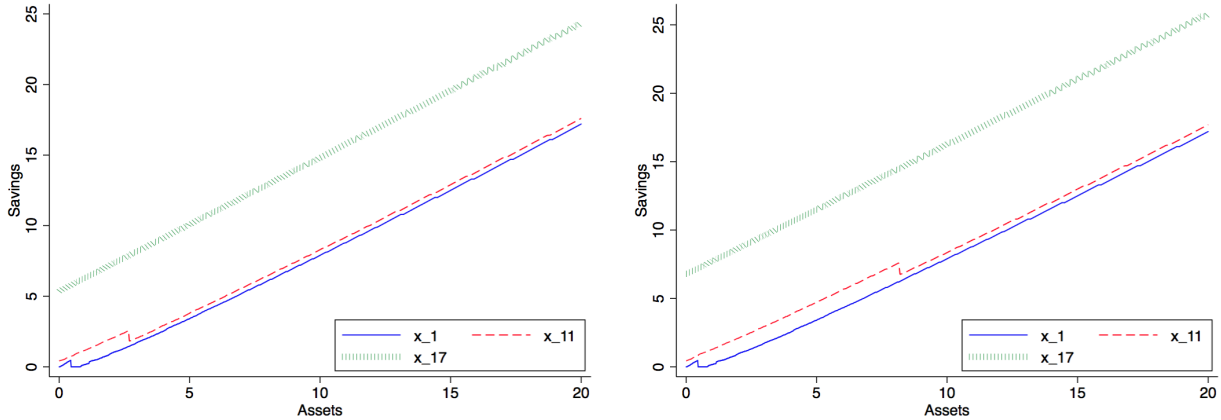

Figure 2. Savings policies for inexperienced (left) and experienced individuals (right), incomplete markets.

more assets are more willing to wait and see whether the island productivity improves, rather than pay the mobility cost κ. Finally, agents on an island with very high productivity x^{17} do not move.

Under complete markets, mobility is independent of assets and agents act to maximize the present discounted value of income. This requires that all agents move away from all islands with productivity less than a threshold value.

Figure 2 shows the savings policies in the incomplete markets model. The left panel of the figure shows the savings policy $g^a(x, 0, a)$ for inexperienced agents; the right panel shows the corresponding policy $g^a(x, 1, a)$ for experienced agents. As expected, future assets are increasing in current island productivity and in experience (each of which corresponds to higher current labor income). The policy for future assets is in general increasing in current assets. However, the zero-one mobility choice causes a discontinuity in the savings policy at the asset level at which the agent is indifferent about whether or not to move. For slightly lower asset levels, the agent works, does not pay the mobility cost, and saves; for slightly higher asset levels the agent moves, earns a low current labor

Variable	K	Y	C	Mob. rate	Frac. exper.	L (Raw)	L (Eff. units)
Benchmark	11.2	3.74	2.75	0.187	0.448	0.906	2.02
Complete markets	8.32	3.47	2.70	0.237	0.398	0.882	2.13
(CM/IM)-1	-0.26	-0.07	-0.02	0.26	-0.11	-0.02	0.05

Table 2. Economic Aggregates

Variable	w	r
Benchmark	1.19	0.0400
Complete markets	1.05	0.0703
(CM/IM)-1	-0.12	0.76

Table 3. Prices

income, pays the mobility cost, and expects a future increase in labor productivity in case a better island is drawn; all these reasons lead to lower asset accumulation in the current period.

4.2 Economic aggregates

Table 2 reports results for the basic economic aggregates. The capital stock is higher in steady state in the benchmark than under complete markets; this is a standard result in Bewley models, although given that effective labor supply is endogenous to the mobility decisions of agents, it was not guaranteed here (Marcet, Obiols-Homs, and Weil, 2007). The lower capital stock leads to slightly lower aggregate output, despite the slightly higher effective labor supply that arises from greater occupational mobility under complete markets. Consumption is also slightly lower under complete markets, although by a much smaller fraction than aggregate output, consistent with lower depreciation as a result of the lower capital stock.

Much more striking are the differences in mobility rates across the two market environments. Mobility is 26 percent higher in the complete markets steady state, as agents move whenever it increases the present discounted value of labor income. Under incomplete markets, the need to smooth consumption by conserving assets and not paying the mobility cost and forgoing earnings looms larger. The flip side of higher mobility is lower raw labor supply (these variables sum to unity by construction). It also ensures that agents are less likely to have become experienced in their occupation under complete markets. Despite these two offsetting forces, the distribution of agents across island productivities is much improved under complete markets, leading to an effective labor supply 5 percent higher under complete markets.

Table 3 reports the corresponding results for prices. The lower aggregate capital stock and higher effective labor supply under incomplete markets lead to a sharp increase in the marginal product of capital, and hence in the interest rate. There is a corresponding reduction in the marginal product of labor and the wage.

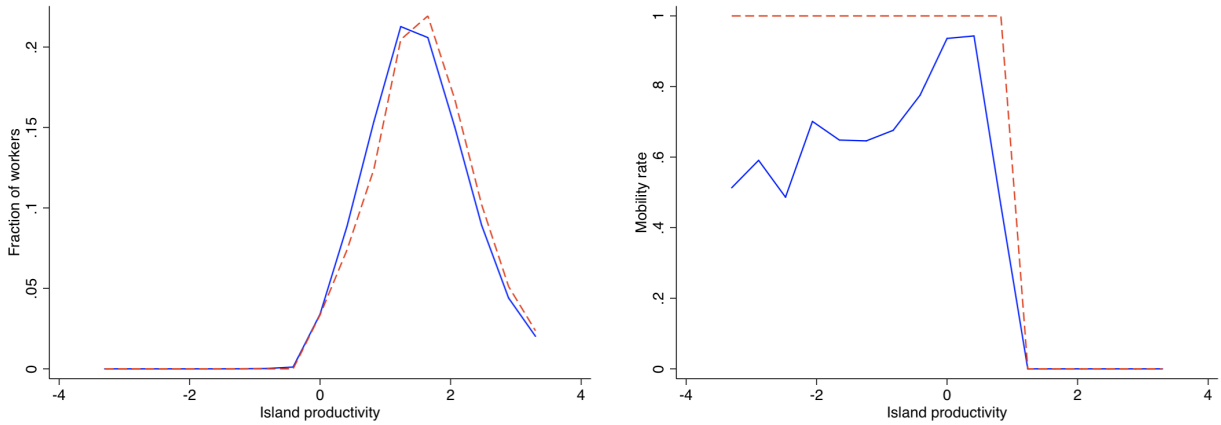

Figure 3. Left panel: Distribution of workers by island productivity.
Right panel: Mobility rate by island productivity.
(Blue solid line: benchmark; red dashed line: complete markets.)

4.3 Cross-sectional features

The most striking effect of the market environment is that under complete markets, agents are much more concentrated on productive islands. The left panel of Figure 3 shows this graphically. It is immediately apparent that the distribution of agents across islands under complete markets dominates that in the benchmark, in the sense of first-order stochastic dominance.

The reason for the improvement in the distribution of workers over island productivity under complete markets must arise from a difference in the probability of occupational switching conditional on island productivity in that environment. This can be seen directly in the right panel of Figure 3. Under complete markets, agents leave an occupation if and only if its productivity falls below the threshold at which the expected present discounted value of future labor income, net of mobility costs, is increased by moving. When markets are incomplete, however, agents do not move as frequently. Agents on low-productivity islands likely have low assets, due to a history of negative productivity shocks leading to repeated costly mobility.

Because agents are more concentrated on productive islands in the complete markets steady state, the dispersion of wages is also lower. The variance of log wages for agents who do not move, and therefore work for the entire period, falls from 0.38 in the incomplete markets benchmark to 0.31 when markets are complete. The fall in the dispersion of log wages is smaller when moving workers are taken into account; this is a compositional effect arising from the fact that occupational mobility is higher in the complete markets model.

Note that the dispersion of log wages in the model is slightly larger than that reported by Kambourov and Manovskii (2009a). Kambourov and Manovskii report that in the PSID for the period 1993-96, the variance of log wages was 0.354; however, part of this variation projects on observable heterogeneity in race, sex, age, and education from which we abstract in our model. However, much of the variation in wages occurs within narrowly-defined groups of observationally-equivalent workers. Therefore, we prefer to match Kambourov and Manovskii's preferred measure

Statistic	Incomplete Markets	Complete Markets
Variance of log wages (excluding moving workers)	0.38	0.31
Variance of log wages (all workers)	0.50	0.49
Variance of log consumption	0.46	0.09
Variance of consumption growth	0.07	0.00
Autocorrelation of log consumption	0.96	1.00
Correlation of log consumption with labor income	0.79	0.00
Correlation with assets	0.93	n.a.
Correlation with island productivity	0.60	0.00
Consumption Gini coefficient	0.33	0.19
Consumption log 90/10 ratio	2.41	0.90
Wealth Gini coefficient	0.50	n.a.

Notes: Statistics derived from a simulated panel of 100,000 individuals.

Table 4. Cross-sectional consumption statistics

of wage variation (their Within-Group 2 measure) for which they report a variance of log wages of 0.293. In a future version of the model, we will change the calibration so as to better hit this target. This will slightly reduce the effects of market incompleteness from those reported in the current version.

Under incomplete markets, uninsurable labor income risk implies that consumption varies both in the cross-section and over time for each individual agent. Table 4 reports key statistics on consumption. As can be seen, the cross-sectional variance of consumption is very high, and consumption is volatile and highly correlated with current income, assets, and island productivity, all of which indicate that markets are substantially incomplete.

By contrast, in the steady state under complete markets, consumption is constant for each individual agent, but the cross-sectional variance of consumption is not uniquely determined. Throughout the paper, we report consumption statistics for the complete markets model that arises after the completion of a transition process of an economy which begins in the steady state of our benchmark incomplete markets model, in which at time 0 complete markets for future idiosyncratic and occupational risk are opened. The wealth of an agent in this model is given by the expected present discounted value of her future labor income net of mobility costs, plus her assets inherited from the incomplete markets environment. She chooses future mobility to maximize the present value of her income, then chooses consumption according to her lifetime budget constraint. This generates a cross-sectional variance of log consumption of 0.09, dramatically less than the corresponding variance of log consumption in the benchmark steady state of 0.46. Because mobility is independent of wealth, consumption in the complete markets steady state is therefore uncorrelated with labor income, earnings, assets, or island productivity, and is perfectly autocorrelated.

4.4 Welfare cost of incomplete markets

4.4.1 Comparison of steady states

Our main results concern the welfare gains of complete markets in the model of occupational mobility that we study. We measure welfare gains as equivalent variation: what fraction would we need to increase an agent's consumption in every period under incomplete markets so as to make her indifferent to suddenly being transferred, with her current island productivity and assets, into the steady state of the complete markets economy? Table 5 reports the basic result that the average welfare gains are very large, and average 12.2 percent of consumption.

There is some variation across agents in the gains from introducing complete markets, which arises from the heterogeneity in current island productivity, experience, and assets at the time of the introduction. This variation can be seen in Figure 4, which reports the average welfare gains conditional on assets, and Figure 5, which reports the average welfare gains conditional on island productivity and experience. In Figure 4, we show the gains for agents with three different island productivity levels $x^{10} < x^{13} < x^{17}$, respectively the tenth percentile, the median, and the maximum of the ergodic distribution of agents across island productivities.

The benefits of complete markets are most pronounced for those with low assets and those located on unproductive islands, who gain from two sources: they can immediately make occupational switches to more productive islands which increase the present value of their labor income (net of mobility costs), and they can increase their consumption by borrowing against their future labor income. It is noticeable also that agents with high assets gain substantially from the transition to complete markets. This is a general equilibrium effect: because the capital stock is substantially lower under complete markets, the interest rate rises, benefiting agents who hold substantial assets when complete markets are introduced.

To make these intuitions more precise, we also report welfare effects from two experiments that aim to distinguish the pure partial equilibrium effect of completing markets from the pure general equilibrium effect of price changes. We define the price-constant, partial equilibrium welfare gain as the equivalent variation associated with providing the agent with complete markets against idiosyncratic and occupational risk, but holding factor prices w and r constant at the levels associated with the benchmark incomplete-markets steady state. We define the general equilibrium welfare gain as the equivalent variation associated with preserving the incomplete market structure of the benchmark model, but exogenously altering prices to the values they take under the complete markets steady state. (Of course, neither experiment is consistent with steady-state equilibrium, since prices are endogenous in this model, but we can still calculate welfare gains for agents exogenously subject to such prices and market structures.)

The price-constant gains exceed the full welfare gains: they are as high as 33 percent. Again there is substantial variation in the distribution of these gains across agents. Rich agents no longer benefit from a high interest rate, but the gains for poor agents are enhanced (because the wage per efficiency unit of labor is higher under incomplete markets, due to the higher capital stock).

	Overall	PE component	GE component	Overall including transition
Average equivalent consumption variation	0.122	0.330	0.030	0.127
Standard deviation of consumption variation	0.00	0.24	0.06	0.10

Table 5. Average Welfare Gains

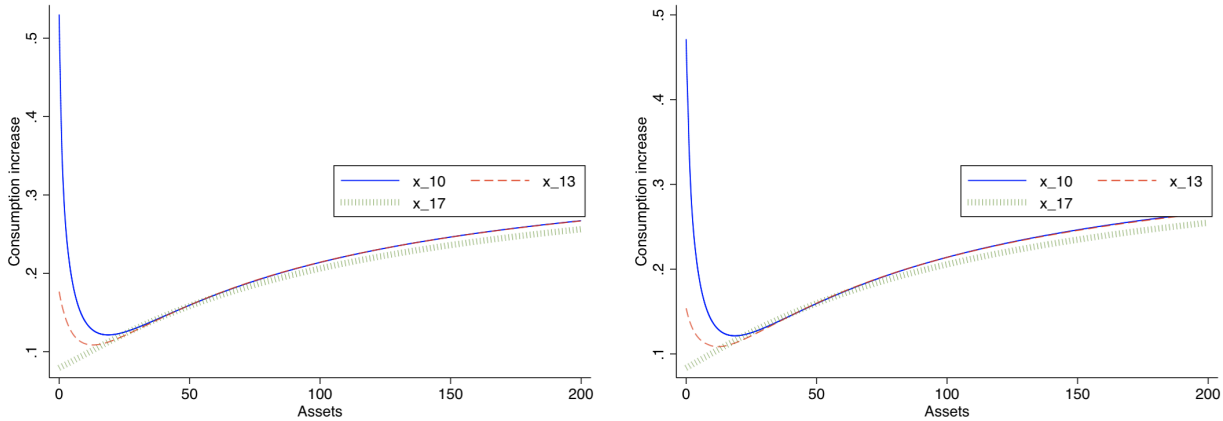

Figure 4. Overall welfare gains for inexperienced (left) and experienced (right) individuals.

The distribution of price-constant welfare gains by assets is shown in Figure 6, and that by island productivity and experience as the uppermost curve in Figure 8. The general equilibrium effects are relatively small, 4 percent on average, and mostly arise from the large change in the interest rate, which particularly benefits rich agents. This can be seen in Figure 7 and the lowest curve in Figure 8.

4.4.2 Allowing for the transition

Welfare gains are slightly higher if we allow for the transition to the steady state after the introduction of complete markets for idiosyncratic and occupational risk into the incomplete markets steady state. The average equivalent variation increases from 12.2 percent to 12.7 percent. The reason for this is the same as in Pijoan-Mas (2006): the capital stock is higher in the steady state of the benchmark incomplete markets economy, and during the transition, agents consume this capital stock. In addition, there is a period while capital remains higher than in the steady state, which increases wages and reduces the interest rate. This benefits especially those agents who are located on productive islands when the transition begins.

It is not surprising that the welfare gains in transition do not differ significantly from those obtained by more simply comparing steady states, since the transition is quite rapid. The time path for the transition of the key aggregate variables, K and L, as well as the key prices r and w, can be seen in Figure 9. Variables are shown as log deviations from their complete-markets steady state values. Notice that labor rises during the transition, as agents choose mobility policies that

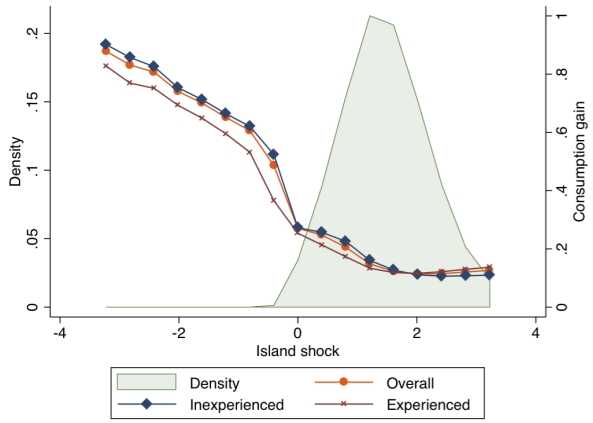

Figure 5. Distribution of welfare gains by island and experience (right scale). Shaded: distribution of individuals across islands (left scale).

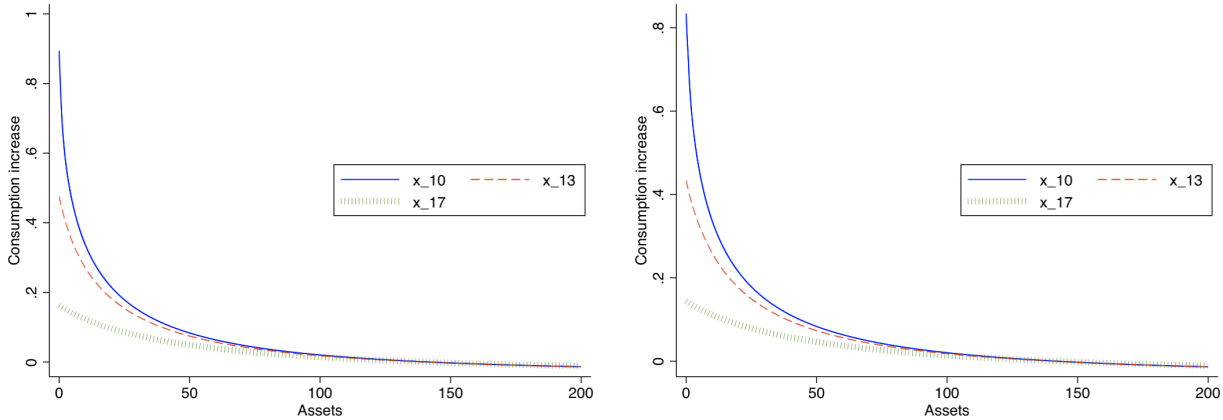

Figure 6. Price constant welfare gains for inexperienced (left) and experienced (right) individuals.

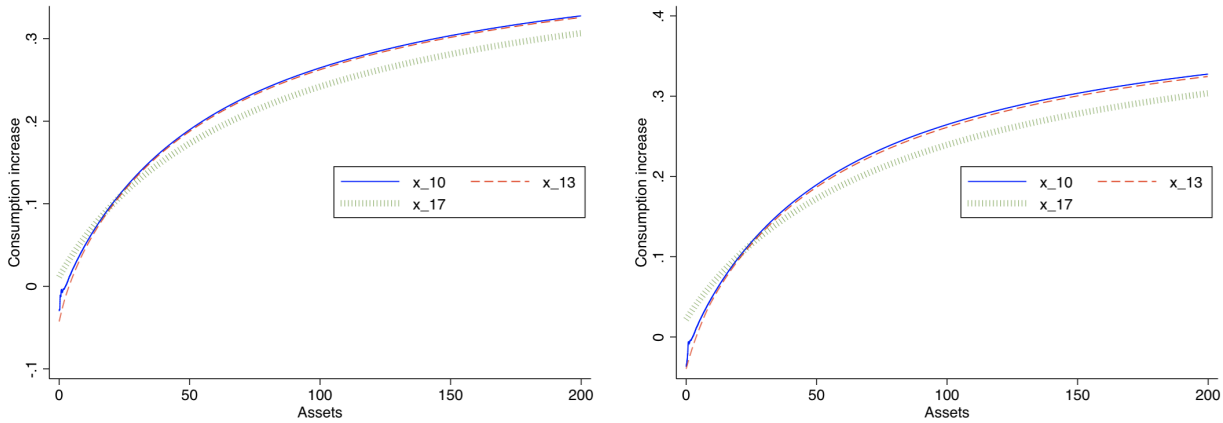

Figure 7. GE welfare gains for inexperienced (left) and experienced (right) individuals.

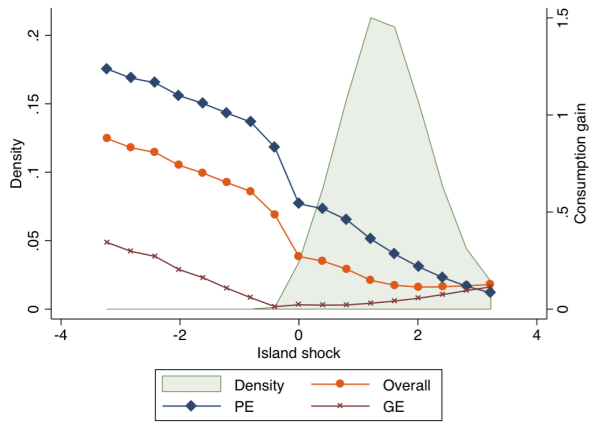

Figure 8. Distribution of welfare gains by island and experience level: overall, price-constant, and general equilibrium effects.

are not constrained by their asset position.

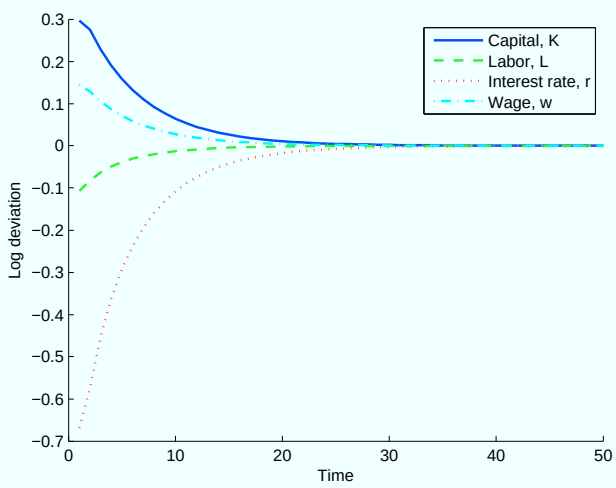

Figure 9. Transition to the complete markets steady state.

4.5 Robustness

Some readers might be concerned that our results may be dependent on our particular choice of parameterization. In a future version of the paper, we will give a more complete robustness check to show how our positive and normative results depend on the parameterization.

In this version of the paper, we show instead how two of the key parameters of the model affect the results in partial equilibrium. The exercise presented here is best thought of as showing how the model is identified, since the exercise reported here involves changing a single parameter, holding constant all other variables including the key prices, w and r. Thus, except in the baseline calibration, the results shown below do not correspond to equilibria of our model, since the capital market does not clear.

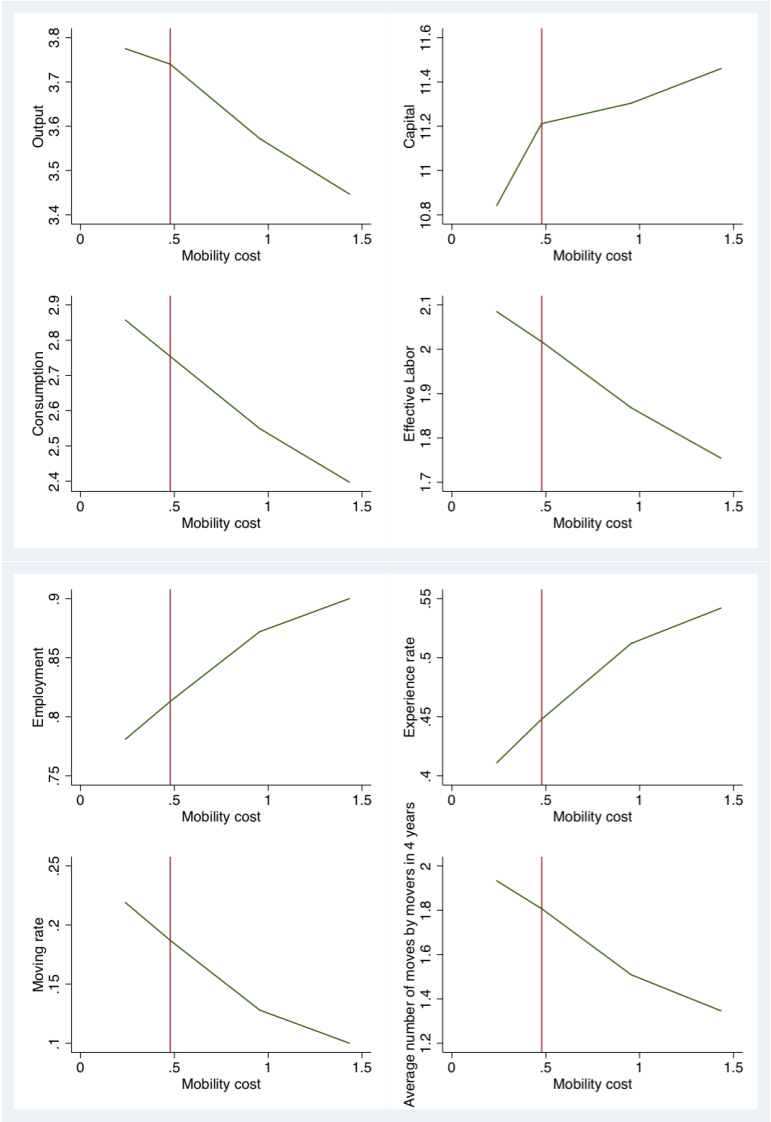

Figure 10. Impact of mobility cost κ on the steady state

Notes: The figure plots the steady state as a function of the moving cost κ. The vertical line indicates the baseline calibration of this parameter.

Figure 10 and Figure 11 show how the steady state of our benchmark incomplete markets model vary with two of the key parameters, the mobility cost κ and the directedness of search, d.

Figure 10 shows the effect of increasing the mobility cost in a range of one month to six months of median wages. (Our benchmark calibration of this paramter was two months of median wages.) As the mobility cost increases, mobility and repeat mobility decrease, and correspondingly, workers' probability of being experienced increases. However, this comes at a cost: workers are less likely to be located on productive islands, and accordingly, effective labor supply falls even as mobility decreases (so that raw labor supply increases). Asset holdings increase as precautionary savings rise because agents endogenously face more variable labor incomes.

Figure 11 shows the effect of changing the directedness of search. Recall that agents draw from the top $1 - d$ quantiles of the island productivity distribution when sampling a new island.

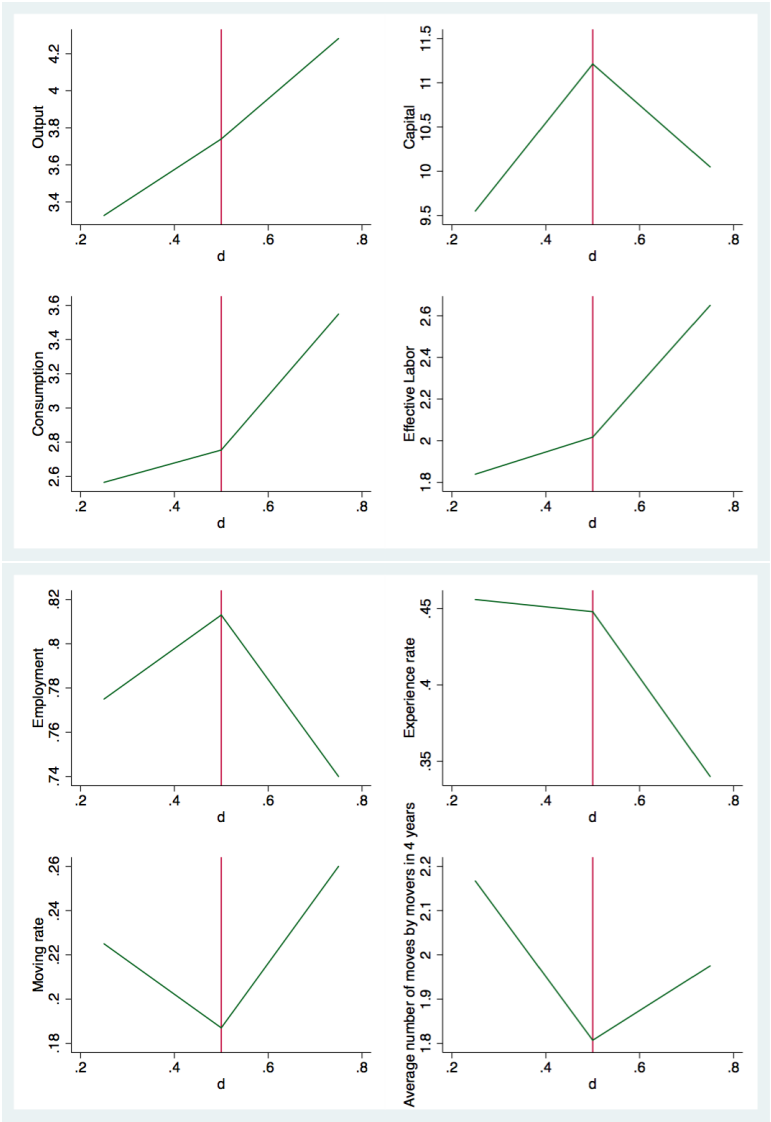

Figure 11. Impact of search directedness d on the steady state

Notes: The figure plots the steady state as a function of the directedness of search d. The vertical line indicates the baseline calibration of this parameter. A value of 0 represents the case of fully uninformed or random search.

When d is small, search is random. This leads to higher repeat mobility, as moving agents are more likely to land on very low productivity islands and choose to move again. The allocation of agents to islands is then worse, and accordingly consumption and output are lower. When d is large, search is well-directed. Mobility is again high, as agents become much pickier about which islands to remain on. Effective labor supply rises as agents are located on better islands, and consumption and output rise. Asset accumulation, that is, precautionary savings, fall together with the (endogenous) decrease in labor income risk due to increased mobility.

5 Policy experiment: the Effects of a Training Subsidy

We have so far reported the effects of market incompleteness on occupational mobility and on welfare by comparing two extreme environments, namely, a benchmark incomplete markets environment with no borrowing and a complete markets equivalent. However, an alternative way to understand the effects of market incompleteness is to consider the effects of policies that relax the constraints on occupational mobility while preserving the basic incomplete market structure of the benchmark model. In this section we consider the effect of a specific policy designed to encourage occupational mobility.

We assume that a benevolent government subsidizes mobility by paying half of the cost of training. This reduces the cost of mobility faced by agents from κ (which was equal to two months of wages of the median worker in the benchmark environment) to $\kappa/2$. The government finances the subsidy using a distortionary tax on labor income. Denote the tax rate by τ. Then the value of working $V^w(\cdot)$, which was given by (1) in the benchmark, now satisfies

$$\begin{aligned} V_w(x,e,a) &= \max_{c,a'} u(c) + \beta \sum_{x'} \sum_{e'} V(x',e',a') f(x,x') \eta(e,e') \\ \text{s.t.} \qquad & c + a' = (1+r)a + (1-\tau)(1+\chi)^e x w \bar{h}_w \\ & a' \geq \underline{a} \qquad \text{and} \qquad c \geq 0. \end{aligned}$$

The value of moving, previously given by (2), is now given by

$$\begin{aligned} V_m(x,e,a) &= \max_{c,a'} u(c) + \beta \sum V(x',0,a') \psi^m(x') \\ \text{s.t.} \qquad & c + a' = (1+r)a + (1-\tau)(1+\chi)^e x w \bar{h}_m - \frac{1}{2}\kappa \\ & a' \geq \underline{a} \qquad \text{and} \qquad c \geq 0. \end{aligned}$$

We assume that the government chooses the tax rate τ to balance the budget. It achieves this using a tax rate of 2.1 percent.

Table 6 reports the effects on economic aggregates of this policy. We show results for the new steady-state which arises once the subsidy and tax have been imposed. As expected, mobility and repeat mobility increase; because of this, mechanically, raw labor supply (that is, total hours

Variable	Y	K	C	Mob. rate	Frac exper.	L (Raw)	L (Eff. units)
Benchmark	3.74	11.2	2.75	0.187	0.448	0.906	2.02
Mobility Subsidy	3.75	10.6	2.80	0.219	0.411	0.890	2.08
Percent Change	0.002	-0.05	0.02	0.17	-0.04	-0.02	0.03

Table 6. The Effects of Subsidizing Mobility Costs

worked) falls. However, the increased mobility leads to better occupational match quality, so that labor supply in effective units increases by 3 percent. Because the mobility subsidy allows workers to move more easily when hit by repeated bad island productivity shocks, precautionary savings fall, leading to an increase in the interest rate and a fall in the wage. This offsets the improvement in welfare due to the better island-level allocation of labor.

Table 6 reports the effects on economic aggregates of this policy. We show results for the new steady-state which arises once the subsidy and tax have been imposed. As expected, the moving cost subsidy is able to increase overall mobility rate. Compared to the benchmark economy, mobility in the subsidized economy is 3 percentage points higher. This difference is large: even under complete markets, mobility was only 5 percentage points higher than in the benchmark. As a consequence of increased mobility, the fraction of experienced agents in the subsidy economy is almost 4 percentage points lower than in the benchmark. Just as in the case of complete markets, this highlights how increased occupational mobility leads to a more efficient allocation of workers across islands. Indeed, the only way to reconcile higher effective labor in the face of higher mobility and lower experience is that workers must be better allocated to the most productive islands.

Output under the mobility subsidy is essentially identical to the baseline model. This is the result of two opposing effects. With a subsidized mobility cost there is less of a need to self-insure against negative occupational shocks that result in occupational switches. As a result capital falls slightly, and this leads to a 3 percent reduction in the wage per efficiency unit of labor.

The welfare improvement associated with the policy is small. As before, we calculate welfare in the sense of equivalent variation, asking what percentage increase in lifetime consumption would be required to make an agent indifferent between the benchmark environment and the economy with the mobility subsidy. To make this welfare comparison well-defined, we calculate welfare behind the veil of ignorance, asking an as-yet-unborn agent the value p such that he is indifferent between two options, first, receiving the consumption path associated with a randomly-drawn agent from the ergodic distribution of the benchmark economy, increased by the factor $1 + p$, and second, receiving the consumption path associated with a randomly-drawn agent from the economy with the mobility subsidy. The value of p that makes the agent indifferent is 0.2 percent. This result is not surprising: as already noted, the mobility subsidy does improve the effective allocation of labor, but it has an offsetting general equilibrium effect and lowers the wage. These effects almost exactly offset each other.

6 Occupational Mobility among the Young

We assume in our benchmark model that agents are infinitely-lived. This is convenient for expositional purposes; however, an important limitation is that in such a model, we abstract from life-cycle variation in occupational mobility. In fact, because borrowing constraints are more likely to be binding for young agents, the effect of market incompleteness can be more significant for these agents. In this section we argue that this is quantitatively significant.

To model young agents, we consider the thought experiment of introducing a cohort of small measure of agents into the steady state of our benchmark model. We imagine that the initial occupation of each worker in this cohort is randomly drawn according to the ergodic distribution of island productivities, $\Psi(\cdot)$. Each agent in the cohort starts off with no assets. Because this cohort is small, it does not affect the equilibrium, and in particular, equilibrium prices w and r are unchanged. It follows that the optimal policy for agents in the new cohort are the same as those in the benchmark model. The only difference between the new cohort and other agents is that the cross-sectional distribution of the new agents by island productivities, experience, and assets are not the same as the ergodic distribution μ (the newborns are all inexperienced and have zero assets, and their productivity distribution is dominated, in the sense of first-order stochastic dominance, by the distribution for existing agents). Finally, to understand the effects of incomplete markets on occupational mobility and on welfare, we also conduct the same experiment in a complete markets environment. We do this in the complete markets steady-state, although the results would be essentially unchanged if we conducted a partial equilibrium analysis in the sense of the previous section by keeping w and r at the values from the incomplete markets steady state.

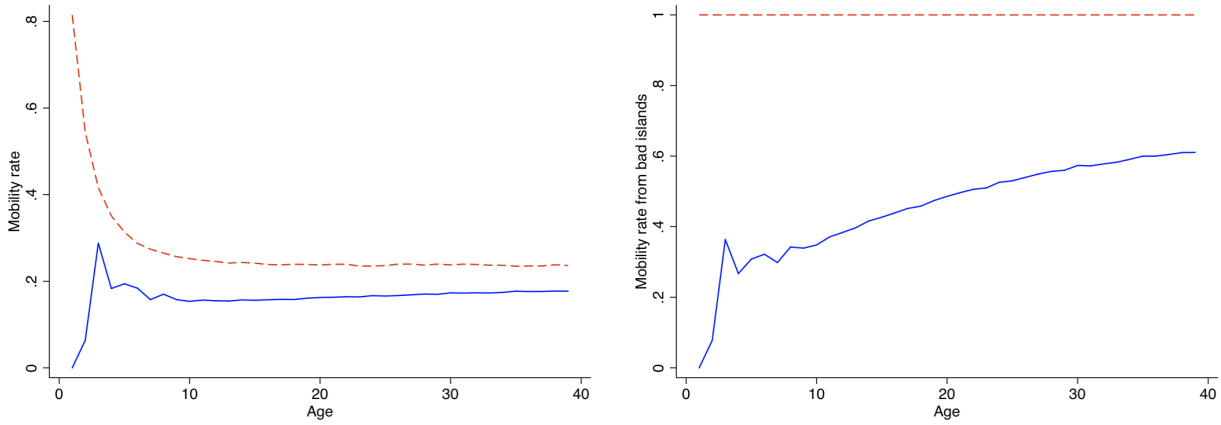

Figure 12. Young worker experiment. Blue solid line: benchmark; red dashed line: complete markets.
Left panel: Average mobility, by cohort age.
Right panel: Mobility rate conditional on positive expected present discounted value of moving, by cohort age.

The results of this experiment are shown in Figures 12, 13, and 14. Each graph presents a simulated time series of a particular variable for the cohort of newborn agents, the solid blue line showing the benchmark (incomplete markets) model and the red dashed line the complete markets

model. The age of the agents in the cohort under study (that is, the number of periods since their introduction into the model) is measured on the horizontal axis in each plot. Figure 12 shows mobility. While even in steady state occupational mobility is higher under complete markets, the difference is much starker for the new cohort of financially-constrained agents. Initial mobility exceeds 50 percent annually for several years under complete markets, as initially-unlucky agents seek more productive occupations; in the incomplete markets environment, on the other hand, young agents cannot pay the mobility cost and so do not move. The right panel of Figure 12 shows this difference in mobility even more starkly, by showing mobility rates conditional on a worker being located on an island with productivity low enough that the expected present discounted value of wages of the worker is increased by leaving the island. Under complete markets, any worker on such an island leaves immediately, while in the incomplete-markets benchmark, most workers on such islands choose not to pay the cost of moving.

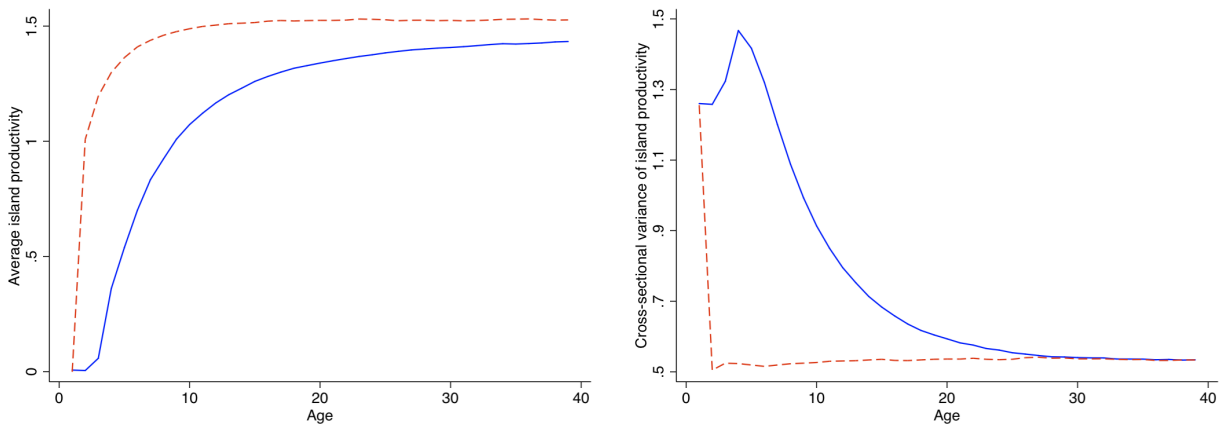

Figure 13. Young worker experiment. Blue solid line: benchmark; red dashed line: complete markets.
Left panel: Average island log productivity, by cohort age.
Right panel: Cross-sectional variance of island log productivity, by cohort age.

Figure 13 shows the effect of reduced mobility under incomplete markets for productivity. The left panel shows average log island productivity. In both market environments, average productivity improves with cohort age as workers relocate out of unproductive occupations, but the transition is much more protracted under incomplete markets. The differences in expected log occupation productivity for young workers substantially exceed the long-run differences. The right panel of Figure 13 shows the cross-sectional variance of productivity, which also falls much more slowly under incomplete markets.

Finally, Figure 14 shows the cross-sectional variance of labor earnings (conditional on employment) and of consumption. It is striking that the variance of log labor income is hump-shaped in the benchmark: initially-lucky agents increase their assets, become better-insured, and move away from their occupation if it receives a negative productivity shock, while initially-unlucky agents cannot use this insurance mechanism. Under complete markets the cross-sectional variance of log labor income is essentially constant. As always, consumption shows the importance of complete

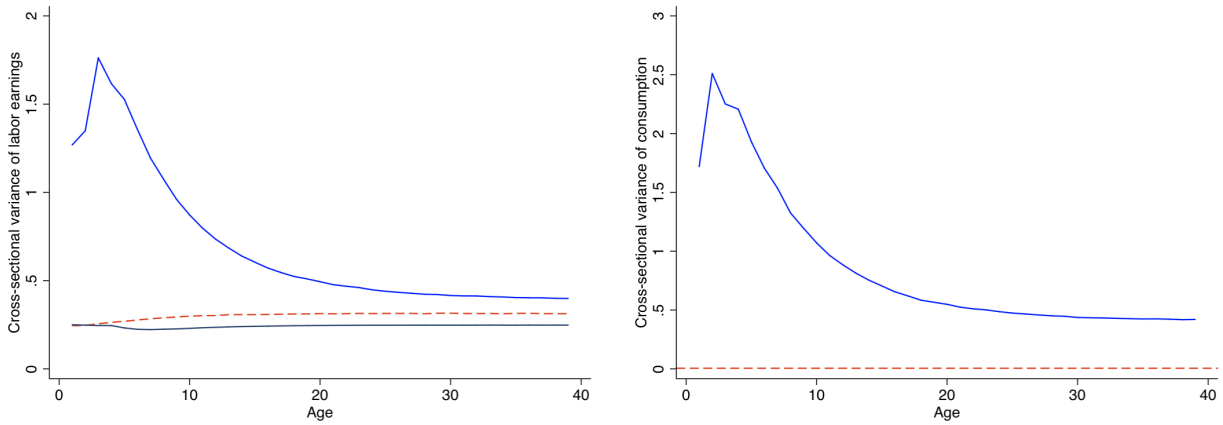

Figure 14. Young worker experiment. Blue solid line: benchmark; red dashed line: complete markets. Left panel: Variance of log labor income conditional on working, by cohort age. Right panel: Variance of log consumption, by cohort age.

markets most strikingly: in the incomplete market environment, the variance of log consumption tracks that of labor income[11] while under complete markets, consumption is essentially constant across agents.[12].

In summary, the effects of market incompleteness are substantially exacerbated for young, poorly-insured agents in our model. This suggests that average welfare effects could be even larger in a life-cycle version of our model. Constructing such a model would allow us to incorporate two important life-cycle effects that are missing in the infinite-horizon model in the current paper. First, finite horizon effects are quantitatively relevant near the end of the life-cycle, since the future income gain from occupational mobility decreases as the remaining working lifetime falls. Second, for the model to be consistent with the observed decline in occupational mobility by age (Kambourov and Manovskii, 2008), it is probably important to allow for agents to learn about their own occupational match quality, as in Neal (1999). We leave constructing a model with these features for future research.

7 Conclusion

In this paper we study the effects of financial market incompleteness on occupational mobility, motivated by the fact that occupation-level earnings shocks are large and highly persistent, and therefore difficult for workers to insure against. Occupational choice is modeled using an equilibrium search model where the returns to working in an occupation are stochastic, and occupational mobility is costly. Unlike the existing literature on occupational mobility, we relax the assumption

[11]Note that the distribution of labor earnings reported in the left panel of Figure 14 omits agents who switch occupations and have zero labor income; it is therefore not surprising that consumption variance (for all agents) can exceed income variance for the employed. This is reinforced by the highly persistent nature of occupation productivity shocks.

[12]Consumption is precisely equated across agents under complete markets if agents can insure themselves, behind the veil of ignorance, against their initial island productivity. It is very small (0.0052) if this market is missing.

of complete markets and allow agents to self-insure by saving using a risk-free bond. Relative to the existing literature on incomplete markets, our paper adds a novel feedback mechanism from incomplete markets to the process for future labor income.

Our calibrated model suggests that the effects of market incompleteness on occupational mobility are quantitatively large. Relative to a comparable complete markets framework, mobility in our preferred calibration is 21 percent lower. Importantly, this leads to a reduction in labor productivity as more agents work in less productive occupations. We find that the welfare costs of market incompleteness can be as large as 13 percent of lifetime consumption.

We see two important and complementary directions of future research. First, our model has the prediction that agents with low assets find mobility too costly and therefore end up with lower future labor income. Given that this is the key mechanism in our model, verifying this prediction empirically with panel data on wealth, employment, and wages is crucial. Second, our welfare analysis suggests that the effects of market incompleteness can be larger when taking into account life-cycle differences across agents. Extending our model along this dimension is another potentially fruitful avenue to investigate.

References

Aiyagari, S. Rao. 1993. "Uninsured Idiosyncratic Risk and Aggregate Saving." Working Paper 502, Federal Reserve Bank of Minneapolis, Minneapolis, MN.

———. 1994. "Uninsured Idiosyncratic Risk and Aggregate Saving." *Quarterly Journal of Economics* 109 (3):659–84.

Altonji, Joseph G. and Robert A. Shakotko. 1987. "Do Wages Rise with Job Seniority?" *Review of Economic Studies* 54 (3):437–459.

Alvarez, Fernando and Robert Shimer. 2011. "Search and Rest Unemployment." *Econometrica* 79 (1):75–122.

Alvarez, Fernando and Marcelo Veracierto. 1999. "Labor-Market Policies in an Equilibrium Search Model." In *NBER Macroeconomics Annual*, vol. 14, edited by Ben S. Bernanke and Julio J. Rotemberg. Cambridge, MA: MIT Press, 265–304.

Banerjee, Abhijit V. and Andrew F. Newman. 1993. "Occupational Choice and the Process of Development." *Journal of Political Economy* 101 (2):274–298.

Bewley, Truman F. 1986. "Stationary Monetary Equilibrium with a Continuum of Independently Fluctuating Consumers." In *Contributions to Mathematical Economics in Honor of Gerard Debreu*, edited by Werner Hildenbrand and Andreu Mas-Colell. Amsterdam: North-Holland, 79–102.

Broda, Christian and David E. Weinstein. 2006. "Globalization and the Gains from Variety." *Quarterly Journal of Economics* 121 (2):541–585.

Buera, Francisco J. 2007. "Persistence of Poverty, Financial Frictions, and Entrepreneurship." Unpublished.

———. 2009. "A dynamic model of entrepreneurship with borrowing constraints: theory and evidence." *Annals of Finance* 5 (3-4):443–464.

Buera, Francisco J. and Yongseok Shin. 2011. "Self-insurance vs. self-financing: A welfare analysis of the persistence of shocks." *Journal of Economic Theory* 146 (3):845–862.

Cagetti, Marco and Mariacristina De Nardi. 2006. "Entrepreneurship, Frictions, and Wealth." *Journal of Political Economy* 114 (5):835–870.

Chang, Yongsung and Sun-Bin Kim. 2006. "From Individual to Aggregate Labor Supply: A Quantitative Analysis Based on a Heterogeneous Agent Macroeconomy." *International Economic Review* 47 (1):1–27.

Evans, David S. and Boyan Jovanovic. 1989. "An Estimated Model of Entrepreneurial Choice under Liquidity Constraints." *Journal of Political Economy* 97 (4):808–827.

Filmer, Deon and Lant Pritchett. 1999. "The Effect of Household Wealth on Educational Attainment: Evidence from 35 Countries." *Population and Development Review* 25 (1):85–120.

Foster, Lucia, John Haltiwanger, and C. J. Krizan. 2001. "Aggregate Productivity Growth: Lessons from Microeconomic Evidence." In *New Developments in Productivity Analysis*, edited by Charles R. Hulten, Edwin R. Dean, and Michael J. Harper, chap. 8. Chicago, IL: University of Chicago Press, 303–372.

Goldin, Claudia. 2006. "The Quiet Revolution That Transformed Women's Employment, Education, and Family." *American Economic Review* 96 (2):1–21.

Heathcote, Jonathan, Kjetil Storesletten, and Giovanni L. Violante. 2008. "Insurance and opportunities: A welfare analysis of labor market risk." *Journal of Monetary Economics* 55 (3):501–525.

Heckman, James J., Robert J. Lalonde, and Jeffrey A. Smith. 1999. "The economics and econometrics of active labor market programs." In *Handbook of Labor Economics*, vol. 3A, edited by Orley C. Ashenfelter and David Card, chap. 31. Amsterdam: Elsevier, 1865–2097.

Hsieh, Chang-Tai and Peter J. Klenow. 2009. "Misallocation and Manufacturing TFP in China and India." *Quarterly Journal of Economics* 124 (4):1403–1448.

Huggett, Mark. 1993. "The risk-free rate in heterogeneous-agent incomplete-insurance economies." *Journal of Economic Dynamics and Control* 17 (5–6):953–969.

Kambourov, Gueorgui and Iourii Manovskii. 2008. "Rising Occupational and Industry Mobility in the United States: 1968-97." *International Economic Review* 49 (1):41–79.

———. 2009a. "Occupational Mobility and Wage Inequality." *Review of Economic Studies* 76 (2):731–759.

———. 2009b. "Occupational Specificity of Human Capital." *International Economic Review* 50 (1):63–115.

Katz, Lawrence F. and David H. Autor. 1999. "Changes in the Wage Structure and Earnings Inequality." In *Handbook of Labor Economics*, edited by Orley C. Ashenfelter and David Card, chap. 26. Amsterdam: Elsevier, 1463–1555.

Krusell, Per, Toshihiko Mukoyama, Richard Rogerson, and Ayşegül Şahin. 2008. "Aggregate implications of indivisible labor, incomplete markets, and labor market frictions." *Journal of Monetary Economics* 55 (5):961–979.

Lucas, Robert E., Jr. and Edward C. Prescott. 1974. "Equilibrium Search and Unemployment." *Journal of Economic Theory* 7 (2):188–209.

Marcet, Albert, Francesc Obiols-Homs, and Philippe Weil. 2007. "Incomplete markets, labor supply, and capital accumulation." *Journal of Monetary Economics* 54 (8):2621–2635.

McCall, Brian P. 1990. "Job Matching: A Test of Sorts." *Journal of Political Economy* 98 (1):45–69.

Miller, Robert A. 1984. "Job Matching and Occupational Choice." *Journal of Political Economy* 92 (6):1086–1120.

Neal, Derek. 1995. "Industry-Specific Human Capital: Evidence from Displaced Workers." *Journal of Labor Economics* 13 (4):653–677.

———. 1999. "The Complexity of Job Mobility among Young Men." *Journal of Labor Economics* 17 (2):237–261.

Parent, Daniel. 2000. "Industry-Specific Capital and the Wage Profile: Evidence from the National Longitudinal Survey of Youth and the Panel Study of Income Dynamics." *Journal of Labor Economics* 18 (2):306–323.

Pavan, Ronni. 2011. "Career Choice and Wage Growth." *Journal of Labor Economics* 29 (3):549–587.

Pijoan-Mas, Josep. 2006. "Precautionary savings or working longer hours?" *Review of Economic Dynamics* 9 (2):326–356.

Quadrini, Vincenzo. 2000. "Entrepreneurship, Saving and Social Mobility." *Review of Economic Dynamics* 3 (1):1–40.

Şahin, Ayşegül, Joseph Song, Giorgio Topa, and Giovanni L. Violante. 2011. "Measuring Mismatch in the U.S. Labor Market." Federal Reserve Bank of New York mimeo.

Vereshchagina, Galina and Hugo A. Hopenhayn. 2009. "Risk Taking by Entrepreneurs." *American Economic Review* 99 (1):1808–1830.