Welfare Consequences of Rising Wage Risk in the United States: Self-Selection into Risky Jobs and Family Labor Supply Adjustments*

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Abstract

We investigate the welfare consequences of the rising wage volatility in the United States from the early 1970s to the 2000s. Several important questions are jointly addressed for an effective assessment of the welfare cost caused by the increased wage shocks: whether the increased wage shocks were or were not anticipated, whether they resulted from heterogeneous workers' risk choice, and whether the affected individuals were or were not insured against the changes. We provide a quantitative assessment of the welfare cost using an augmented general equilibrium model with incomplete markets. Heterogeneous risk preferences, job heterogeneity in wage risk, and gender differences in wage dynamics constitute unique features of the model. Analytical results show that the measured welfare cost is substantially overstated by neglecting heterogeneity in risk preferences and workers' risk choice. Family labor supply adjustments are more effective, compared to the borrowing and saving mechanism, in reducing the welfare cost of the increased wage shocks, particularly permanent shocks. Family labor supply adjustments, however, can reduce the welfare cost more effectively when the borrowing and saving behavior is allowed. It is also found that wives increase their labor supply substantially in response to anticipated increases in husbands' permanent wage shocks, and this 'added-worker' effect is mostly accounted for by the extensive margin of wives' labor supply adjustments. These results survive a series of robustness tests.

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I. Introduction

Men's annual earnings have been more volatile in the United States since the early 1970s, with a dramatic increase in measured earnings volatility occurring during the 1970s (see, among others, Dynan et al., 2012; Gottschalk and Moffitt, 1994; Haider, 2001; Shin and Solon, 2011).[1] Men's hourly wages have also been volatile for the same period (e.g., Heathcote et al., 2010). Concurrently, men's hourly wages have stagnated since the late 1970s (e.g., Elsby et al., 2016). This paper concerns the potential welfare loss associated with the increased wage volatility.

More precisely, this paper evaluates the welfare costs of the increased wage volatility from the early 1970s to the 2000s period. As in Blundell et al. (2016), we take wage shocks as the primitive source of uncertainty that each household faces, and view changes in labor hours as the household's optimal responses to the increased shocks. We include the 1970s in the analysis period. In contrast, most studies in the literature on welfare implications of rising inequality focus on the 1980s and 1990s. As noted by Shin and Solon (2011), the dramatic increase in men's earnings volatility during the 1970s preceded the well-documented increase in long-run earnings inequality (more generally, the rise in earnings inequality) observed during the 1980s and 1990s, implying that these two events might have been driven by different causes, and consequently might command different welfare implications. As reliable consumption data are not available for the 1970s, the conventional empirical approach that investigates the relationship between income changes and consumption changes is unfeasible. We therefore estimate a model that describes the early 1970s economy and ask how much welfare costs (in life-time consumption equivalent) an average household of the 1970s economy suffers from when the household faces the higher wage shocks of the 2000s.

A more appropriate welfare evaluation, however, would require simultaneous consideration of the following issues raised by existing studies. As discussed by Blundell et al. (2008) and Cunha et al. (2005), among others, a rise in earnings volatility forms only a necessary condition for welfare loss. Identifying economic risk associated with earnings changes will require further information on whether the changes were or were not anticipated (or even the results of

[1] See Shin and Solon (2011) for a review of the literature on trends in men's earnings volatility.

agents' purposive choice) and whether the affected individuals were or were not insured against the changes. While several recent papers (e.g., Blundell et al., 2008; Blundell et al., 2016; Dynaski and Gruber, 1997; Gorbachev, 2011; Heathcote et al., 2014; Krueger and Perry, 2006)[2] have investigated the effectiveness of various insurance measures by analyzing consumption data in conjunction with the income data, little effort has been made to consider heterogeneity in individual risk preferences and individual choice of job-related wage risk in the welfare analysis of rising volatility. We believe that welfare costs are overstated by neglecting workers' self-selection into risky jobs.

Another shortcoming in the literature of welfare evaluation of the changing wage structure is the lack of examination on the role played by gender differences in observed volatility (trends). As documented by several studies (e.g., Congressional Budget Office, 2007; Dynan et al., 2012; and Ziliak et al., 2011), male earnings have become more volatile, while female earnings have been less volatile since the early 1970s, suggesting that trends in wage volatility might also be different between genders. Existing studies, however, often find rising trends in men's wage volatility and assume equality between genders in wage dynamics when evaluating welfare consequences of the rising wage inequality/volatility (e.g., Heathcote et al, 2010; Hong et al., 2015). We believe that gender differences in wage shock changes have important welfare implications. For example, other things being held constant, a household would make different decisions on consumption and family labor supply adjustments and probably suffer from a greater welfare loss (due to limited insurability) if only the husband's wages are subject to a negative (permanent) wage shock, compared to the case when the same amount of wage shock is shared between the husband and the wife. As suggested by Shin and Solon (2011), a more complete picture of earnings dynamics should combine the patterns by gender and give particular attention to the covariation of spouses' earnings.

This paper contributes to the literature by investigating the aforementioned issues jointly. First and most importantly, we address the issue of individuals' choice of wage risk by allowing

[2] Krueger and Perry (2006) document that rising income inequality has been accompanied by an increase in consumption inequality of a smaller degree because individuals mitigate their income fluctuation through an endogenous credit constraint. Heathcote et al. (2014) find that households are well insured against sharp increases in wage inequality through private- and government-provided insurance. Using relatively old data (from 1980 to 1992), Blundell et al. (2008) show partial insurance on permanent income shocks and almost full insurance on transitory shocks through various insurance mechanisms, such as, taxes, transfers, family labor supply, and durable goods. Gorbachev (2011) shows a lower degree of an increase in consumption volatility compared to the degree of an increase in family income volatility.

in a standard general equilibrium model with incomplete markets heterogeneity in individual risk preferences, job heterogeneity in wage risks, and workers' self-selection into risky jobs. We focus on the bias in the measured welfare cost generated by existing studies. This is done by comparing the estimation results of our augmented model to those of the otherwise comparable homogeneous agent-job model. We also follow several micro-data-based studies in obtaining an empirical distribution of individual risk aversions and allow into the model heterogeneity in risk preferences derived from the actual distribution.[3] To the best of our knowledge, this paper is the first that analyzes the effects of heterogeneous workers' self-selection into risky jobs in the literature of welfare evaluation of the rising inequality/volatility.

Second, as previously noted, an implicit assumption in the literature is that both males and females experience the same evolution in the wage process. This partly reflects the complication associated with identifying women's wage shocks in the presence of their sample selectivity. The importance of the gender issue aforementioned[4] and our ability to cope with the selectivity allow us to take gender differences in the trends and levels of wage shocks into account when analyzing their welfare implications. We estimate the augmented model to identify structural parameters of job-specific wage shocks (permanent and transitory) randomly assigned individuals would experience. Of course, individuals make decisions of not only labor market participation but also the job type, risky or safe. Observed wage shocks are then used as empirical moments to be matched with corresponding model-generated moments. This could be a methodological contribution by itself.

Third, we conduct a quantitative assessment of effectiveness of various insurance measures in mitigating the welfare cost caused by the increased wage shocks, and investigate how the relative effectiveness of each insurance measure is different depending on the nature of the wage shock. While this is not new to the literature, our analyses of interactive effects among insurance

[3] Preference heterogeneity has been an important ingredient of many macroeconomic models. For example, Krusell and Smith (1998) find that allowing heterogeneity in the discount factor across generations has substantial effects on wealth inequality. Cagetti (2003) uses a life-cycle model of wealth accumulation, estimates different discount factors and risk aversion parameters for three different education groups, and explains the importance of precautionary savings on wealth accumulation. Apart from these macro-model-based studies, a series of empirical studies measure risk aversion parameters directly based on individual responses on hypothetical income gambling questions addressed by various surveys, such as the Panel Study of Income Dynamics (PSID), Health and Retirement Study (HRS), and National Longitudinal Study of Youth 79 (NLSY79) (see, among others, Barsky et al., 1997; Kimball et al., 2008, 2009; Sahm, 2012; Light and Ahn, 2010).

[4] In addition, as of 2014, females account for about 47% of the total employment.

mechanisms and cross-responsiveness of labor supply with respect to spouses' wage shocks are relatively new and deserve further attention.

Lastly, various tests are conducted for robustness of the results. For example, we investigate how the households' ability to foresee changes in wage shocks affects the measured welfare costs. We also examine how the measured welfare costs are different depending on whether or not prices and/or other economic conditions are allowed to vary following the increased wage shocks.

Analysis of the Panel Study of Income Dynamics data shows that permanent wage shocks increased similarly for both genders from the early 1970s to the 2000s. While male transitory shocks increased substantially, female ones leveled off. These observed wage shocks, combined with the information on individual risk preferences, are used to identify gender-job-specific wage shocks and their changes over time. We provide a quantitative assessment of the welfare costs caused by these changes in wage shocks using a general equilibrium model with incomplete markets in which married couples choose their life-cycle labor supply, job types, consumption, and savings. Heterogeneous risk preferences, job heterogeneity in wage risk, workers' self-selection into risky jobs along with gender differences in wage dynamics constitute unique features of the model. We also estimate an alternative model that assumes homogeneous risk preferences and only one type of job (so no job selection process) and compare the results to those from our augmented model. Our most important result shows that the welfare cost of the increased wage shocks is significantly exaggerated by neglecting heterogeneity in risk preferences and workers' risk choice.

The estimated welfare cost from our augmented model ranges from 4.91% to 12.44%, depending on whether or not the shocks are anticipated and how the increased wage shocks are distributed between risky and safe jobs. The welfare cost remains substantial at 4.91% even when increases in wage shocks are anticipated, the increased wage shocks are concentrated among risky jobs, heterogeneous workers are allowed to self-select into risky jobs (consequently, risk tolerant workers absorb the entirety of the increased wage shocks), and family labor supply adjustments along with borrow and saving behaviors are allowed. Evidence suggests that self-insurance mechanisms are well functioning, but do not absorb the entirety of the increased wage shocks.

The good news is that the majority of the other analytical results, including relative effectiveness of insurance mechanisms, are robust in a qualitative sense with respect to the underlying assumption about preference heterogeneity, the distribution of the increased wage shocks among preference groups, and/or the expectation of the wage shock changes. To summarize briefly, among the four types of wage shocks, the increased male permanent shock is the dominant contributor to the total welfare cost. The welfare improving effects are generally greater from family labor supply than borrowing and saving adjustments. While, compared to borrowing and saving, family labor supply adjustments are more effective in reducing the costs caused by permanent shocks, transitory shocks are more effectively mitigated by borrowing/saving. What interests us more is the finding of complementarity of family labor supply adjustments and borrowing/saving in mitigating the welfare costs: family labor supply adjustments can reduce the welfare costs of the increased permanent shocks more effectively when the borrowing and saving behavior is allowed. Evidence shows that when households are hit by increased male (female) permanent shocks, added-worker effects by wives (husbands) play a greater role in mitigating the welfare loss, relative to the effects of husbands' (wives') self-labor supply adjustment. It is also found that at least three quarters of the wives' 'added-worker' effect in response to husbands' permanent shocks is accounted for by the extensive margin of wives' labor supply adjustments. These insurance mechanisms stop functioning when the permanent shocks are unanticipated. Lastly, measured welfare costs remain similar whether or not prices are allowed to vary following the increased wage shocks (insignificant general equilibrium effect), and more than 100% of the total welfare cost is offset by the welfare gain generated by the concurrent increase in the total factor productivity.

The rest of the paper is organized as follows. Section II describes some basic facts that motivate our research. Section III presents our models, and Section IV discusses determination of model parameters. Using the estimated models from Section IV, Section V analyzes welfare consequences of the increased wage shocks. Section VI concludes.

II. The Facts

We describe the salient facts motivating our exercise, focusing on gender differences in the trends of permanent and transitory wage shocks. Our empirical evidence is based on a sample from the Panel Study of Income Dynamics (PSID) for 1970-2012, which includes respondents who are married and in the age range of 25-64. We prefer the PSID (the most commonly used longitudinal data set in the volatility literature) to other data sets, such as Social Security earnings data or income data from the Internal Revenue Service, for a number of reasons. Most importantly, while the latter data sets have more accurate information on earnings and larger sample sizes than the PSID, they are not publically available. We believe that replicability of the study results for further development of the issue under consideration is as important as the quality of the data. Additionally, the PSID has been tracking individual earnings and hours in a fairly consistent way for more than four decades, which is essential for the purpose of investigating trends in wage volatility. Availability of wage information in the 1970s is particularly important for the current research purposes for the reasons previously stated.

The literature on earnings/income inequality/volatility often emphasizes the importance of measurement errors inherent in the earnings and hours variables collected from surveys, such as the PSID and the Current Population Survey. Although these measurement errors may distort measured earnings/wage volatility, there is no reason to believe that such errors produce biased results in the trends in measured volatility, which is the focus of the current study. See Appendix 1 for details of our sample.

We start with the empirical questions of whether wage shocks, permanent and transitory, have increased during our sample period, and if so, by how much. The distinction of permanent/transitory is useful because it informs the welfare evaluation of wage changes: not only do permanent and transitory wage shocks have different welfare consequences, but also the effectiveness of each insurance measure is different depending on the nature of the wage shocks. Unlike existing studies, however, stochastic wage processes are modeled separately by gender. On the basis of the standard permanent-transitory decomposition method commonly adopted in the literature,[5] Figure 1 shows how male and female permanent and transitory wage shocks have evolved over time. As well recognized in the literature, the variance of the true transitory wage shock cannot be separately identified from the variance of measurement error featuring most survey-based wage/earnings data. Following Heathcote et al. (2010), among others, we assume that the variance of the measurement error is time invariant, and it is obtained externally from the PSID Validation Study. Using the PSID Validation Study conducted for 1982 and 1986, French (2004) obtains a variance of measurement error in log hourly wages of 0.02, which is subtracted from the estimated variance of each year's transitory shock. In each graph, a dashed line is included

[5] See Appendix 2 and Sections III and IV for details of the estimation procedure.

to represent a trend in variance of each type of wage shock, obtained by the Hodrick-Prescott filter (smoothing parameter=100).

Comparison of each type of wage shock between genders reveals that variances of both permanent and transitory shocks have been greater for females than males, reflecting women's weaker labor market attachment relative to men. More importantly, while variances of permanent shocks have similarly increased for genders, transitory shocks reveal differing patterns by gender in their trends. In particular, unlike males, females have experienced a decrease in transitory wage shocks in the 2000s relative to the early 1970s. To quantify the size of the trend change in wage shocks, we compare the five-year average variance of each shock over the 1970-1974 period with that over the 2002-2006 period. These reference periods are selected to avoid the differential impacts of the recession of the mid-1970s and the Great Recession on wage volatility. The results show that variances of male permanent, male transitory, female permanent, and female transitory shocks have changed from the early 1970s to the 2000s by 0.0078 (from 0.0163 to 0.0241), 0.0288 (from 0.0217 to 0.0505), 0.0078 (from 0.0175 to 0.0253), and -0.01 (from 0.0639 to 0.0539), respectively. These changes correspond to 48%, 133%, 45%, and minus 16%, respectively, when the percentage changes are calculated relative to their 1970s levels. Subsequent sections are devoted to a quantitative assessment of the welfare costs associated with these changes in the four types of wage shocks.

At first, our finding of increased permanent wage shocks for females seems at odds with existing studies (e.g., Dynan et al., 2012; Ziliak et al., 2011), which report that female earnings have been less volatile. A direct comparison, however, would be complicated between these studies and the current one. In addition to their use of earnings instead of hourly wages, these studies adopt a standard deviation of residualized earnings changes as their measure of earnings volatility. As explained by Shin and Solon (2011), an earnings volatility measure based on dispersion of year-to-year earnings change reflects permanent shocks in addition to transitory ones. We, therefore, use the estimates in Figure 1 and derive another wage volatility series for each gender by combining permanent and transitory variances each year. The resulting series show that female wages are slightly less volatile now than four decades ago, when male wages have been more volatile over time.[6] Then, using the current PSID sample but the same method as in existing

[6] Precisely, equation (7) in Shin and Solon (2011) shows that a variance of residualized earnings change is expressed as a sum of variances of permanent shocks and transitory ones. Upon assuming that returns to human capital change

studies,[7] we replicate their finding that female earnings have been less volatile from the early 1970s to the 2000s, and find that the reduction in hours volatility accounts for most of the reduction in earnings volatility for the same sample period.[8] In short, the downward trend in female earnings volatility observed in several existing studies is primarily attributed to the decreasing trend in hours volatility. The mild reduction in female wage volatility is explained by the decrease in transitory wage shocks, and in fact, female permanent shocks have increased substantially during the sample period. Considering that permanent wage shocks are even more consequential than transitory ones, the falling trend in the overall volatility of female wages may in fact cause welfare costs to some degree.

III. Model

We study the welfare effects of the increased wage shocks in a general equilibrium model with incomplete markets in which households choose their life-cycle labor supply, types of jobs, consumption, and savings; a representative firm employs different types of labor across genders, and the government runs a pension system. We estimate and compare two versions of the model: a baseline model which extends the conventional model by allowing individual heterogeneity in risk preferences, job heterogeneity in wage risk, and workers' self-selection into risky/safe jobs, and an alternative (or conventional) model which assumes homogenous risk preference and allows only one type of job. The economies that are described by the baseline and alternative models are called the heterogeneous and homogeneous economies, respectively.

1. Baseline Model

a) Economic environment

The economy is populated by a continuum of households, each of which consists of a married couple. Let $j \in J = \{1,2,\ldots,j_T\}$ denote a period (or 'age') of the life-cycle. Adults in the

over the period of earnings change, it is also affected interactively by the degree of inequality in permanent human capital in the initial year and the change in returns to human capital.

[7] Precisely, we follow Shin and Solon (2011) by computing the standard deviation of residuals obtained from the preliminary regression of a two-year change in log earnings on a quadratic in age each year.

[8] We find that the estimated covariance of hours and wage changes does not show a clear trend for both genders. All these results are available electronically from authors upon request.

household start economic activity at age 1 and retire at j_R , after which they receive a pension of b until j_T. In each period, the household makes decisions on the couple's labor supply, types of 'jobs' (or sectors),[9] and the household's consumption and savings. To be specific, given risk preferences, the household chooses types of jobs, among risky and safe, and the couple's labor supply simultaneously. Job types are identified by a unique characteristic of the wage process: risky jobs are subject to greater wage shocks, compared to safe jobs. Let s^d denote an endogenously determined share of households choosing d-combination of jobs for a husband and a wife: s^1 represents the share of households that choose risky jobs for both the husband and wife; s^2 risky for husband and safe for wife; s^3 risky for husband and non-work for wife; and so on all the way up to s^7non-work for husband and risky for wife; s^8 non-work for husband and safe for wife; and s^9 non-work for both. Obviously, $s^d \in [0,1]$ and $\sum_{d=1}^{D} s^d = 1$.

The household faces uncertainty not only over wages but also life expectancy. They face a probability ξ_j of surviving from age *j-1* to *j*. The household pays flat taxes (τ^k, τ^n) on labor and capital income, and the government uses taxes to finance a public pension system for retirees. In the spirit of Heathcote et al. (2010), once the pension system has been financed, any excess tax revenues are used for government spending.

b) Preferences

Each household maximizes expected lifetime utility over sequences of consumption and the couple's labor supply:

$$E_1 \sum_{j=1}^{j_T} \beta^{j-1} \phi_j u(c_{ij}, n_{ij}^m, n_{ij}^f; \gamma_i), \tag{1}$$

where β is a discount factor with $\beta \in (0,1)$, ϕ_j is the unconditional probability of surviving up to age j with $\xi_j = \frac{\phi_j}{\phi_{j-1}}$, c_{ij} is consumption of household i in age j, n_{ij}^g is labor supply of gender $g \in \{m, f\}$ with m representing a male (or husband) and f a female (or wife), and γ_i is the risk aversion parameter, which varies across households. The period utility function is represented by

[9] In the current study, each 'job', risky or safe, consists of multiple jobs of the same type, and consequently has the meaning of 'sector'. Individuals are allowed to change jobs within each risky or safe 'job' (or sector) or between 'jobs' (or sectors). Jobs and sectors are used interchangeably.

$$u(c_{ij}, n_{ij}^m , n_{ij}^f ; \gamma_i) = \frac{c_{ij}^{1-\gamma_i}}{1-\gamma_i} - \chi^m \frac{(n_{ij}^m)^{1+\sigma_m}}{1+\sigma_m} - \chi^f \frac{(n_{ij}^f)^{1+\sigma_f}}{1+\sigma_f}, \tag{2}$$

where χ^g is a weight on the disutility of labor supply of gender g, and σ_g concerns the Frisch elasticity of labor supply of gender g with the elasticity being determined by $1/\sigma_g$. By allowing different σ values between genders, we capture a decline in the elasticity of labor supply for females and an increase in the elasticity for males from the 1970s to the 2000s.[10] We borrow the functional form from Heathcote et al. (2010), but extend it by allowing heterogeneous risk preferences.

c) Technology

Output Y is produced by a representative firm hiring aggregate capital K and aggregate labor H from competitive markets. The production technology takes a Cobb-Douglas form:

$$Y = ZF(K, H) = ZK^{\alpha}H^{1-\alpha}, \tag{3}$$

where α is the share of capital in the output, and Z is the total factor productivity. Capital depreciates at the rate of δ.

Following existing studies (Katz and Murphy, 1992; Heckman et al., 1998; Heathcote et *al*., 2010), we model aggregate labor input H as an aggregator of two types of inputs, male and female labor, assuming a constant elasticity of substitution between them:

$$H = [\lambda(H^m)^{\theta} + (1-\lambda)(H^f)^{\theta}]^{1/\theta}, \tag{4}$$

where H^m and H^f are male and female labor inputs, respectively, λ is the relative share of male labor input in total labor input, and θ regulates the elasticity of substitution between the two inputs. Changing parameter values of Z and λ capture technological changes and gender-biased demand shifts, respectively.

[10] Blau and Kahn (2007) document a decline in the elasticity of labor supply for married females from 1980 to 2000. Heathcote et al. (2010)'s model also generates consistent results for women, with the estimated elasticity declining from 1.77 in 1967 to 1.25 in 2005.

d) Wages and job choice

Individuals are endowed with efficiency units of labor per market hour, which depend on age (or experience) and the history of idiosyncratic wage shocks. Unlike existing studies, we allow gender differences in the wage process and consider the covariation of spouses' wages.

$$w_{i,j,t}^{g} = \underbrace{p_t^g}_{price\ per\ efficiency\ unit} \times exp(\underbrace{\overbrace{f^g(j_{i,t})}^{deterministic} + \overbrace{z_{i,j,t}^{g}}^{stochastic}}_{efficiency\ unit}), \tag{5}$$

Here, $w_{i,j,t}^{g}$ is the hourly wage rate of an adult in household i who is gender g and age j at time t, p_t^g is the gender-specific price per efficiency unit of labor, $f^g(j_{i,t})$ is the deterministic component of the wage rate which is a function of age, and $z_{i,j,t}^{g}$ is the stochastic component. We assume the stochastic component consists of two orthogonal components: permanent and transitory components. Following Heathcote et al. (2010), among others, the permanent component is assumed to follow an AR(1) process and the transitory one is assumed to be independently distributed random variables. Unlike existing studies, however, we allow individuals to face different stochastic wage processes depending on the type of job they take. Let us index the job type by n, where n represents either a risky (R) or safe (S) job. Thus, it follows that

$$\begin{aligned} z_{i,j,t}^{g,n} &= \underbrace{\nu_{i,j,t}^{g,n}}_{permanent\ component} + \underbrace{\epsilon_{i,j,t}^{g,n}}_{transitory\ component}, \\ \nu_{i,j,t}^{g,n} &= \rho^{g,n}\nu_{i,j-1,t-1}^{g} + \eta_{i,j,t}^{g,n}, \end{aligned} \tag{6}$$

with $\eta_{i,j,t}^{g,n} \sim N(0, \left(\sigma_{\eta_{j,t}}^{g,n}\right)^2)$ and $\epsilon_{i,j,t}^{g,n} \sim N(0, \left(\sigma_{\epsilon_{j,t}}^{g,n}\right)^2)$.

One of the most challenging aspects of the model estimation is to identify these structural parameters: how much wage shocks - permanent and transitory - an individual randomly assigned to a job would face over the course of a job career, and how they are different between risky and safe jobs and between genders. What we observe in the data, however, is wage shocks experienced by those who self-selected into jobs, risky or safe. As will be explained in Section IV, the structural parameters are identified by the Simulated Method of Moments, which effectively minimizes the distance between the vector of structural parameters and a set of observed moments.[11] Finally, for a couple that chooses job type n, the husband's and wife's wage shocks are assumed to be positively correlated as in Hyslop (2001). Precisely,

$$\Sigma_{\text{perm}} = \begin{pmatrix} \left(\sigma^m_{\eta_{j,t}}\right)^2 & \rho_p \sigma^m_{\eta_{j,t}} \sigma^f_{\eta_{j,t}} \\ \rho_p \sigma^m_{\eta_{j,t}} \sigma^f_{\eta_{j,t}} & \left(\sigma^f_{\eta_{j,t}}\right)^2 \end{pmatrix},$$

and

$$\Sigma_{trans} = \begin{pmatrix} \left(\sigma^m_{\epsilon_{j,t}}\right)^2 & \rho_t \sigma^m_{\epsilon_{j,t}} \sigma^f_{\epsilon_{j,t}} \\ \rho_t \sigma^m_{\epsilon_{j,t}} \sigma^f_{\eta_{j,t}} & \left(\sigma^f_{\epsilon_{j,t}}\right)^2 \end{pmatrix}, \tag{7}$$

for the permanent and the transitory shocks, respectively, with $\rho_p > 0$ and $\rho_t > 0$.

e) Decision problem of a household

In each period, a household makes decisions on consumption, saving, types of jobs (or sector) including non-work, along with labor hours. A set of state variables for the household is denoted by $\Omega = \{a, j, \eta^m, \eta^f, \epsilon^m, \epsilon^f\}$, where $a \in \mathcal{A} \equiv [\underline{a}, \infty)$ is current asset holdings with $\underline{a}$ being the borrowing limit. Given the degree of risk preferences, $\gamma \in \Gamma \equiv [\underline{\gamma}, \overline{\gamma}]$, optimal decision rules are a set of functions for consumption, $c(\Omega)$, the couple's labor supply, $n^g(\Omega)$, and asset holdings, $a(\Omega)$, which solve the household problem: each household faces D mutually exclusive alternatives, depending on the couple's choice of job types and labor market participation.

$$V(\Omega\,;\gamma, d) = \begin{cases} \max\limits_{d} \{V_d(\Omega\,;\gamma)\}_{d=1}^{D} & if\ j < J_R,\ \ d = \{1,2,\dots,D\} \\ V(\Omega\,;\gamma) & if\ j \geq J_R \end{cases}, \tag{8}$$

[11] An equilibrium condition requires a higher mean in a job with a greater variance, other things being held constant. Although wage shocks, permanent or transitory, are set to have zero means in both risky and safe jobs, there still exists a wage premium in risky jobs, relative to safe jobs, as long as variances are greater in the former than the latter. This is true, as shocks are defined in log wages. In principle, we could also allow different means in log wage shocks between risky and safe jobs at each stage of the life-cycle, which increases the structural parameters to be estimated by a large number.

where V is the value function for the household problem, and d=1 if the husband and the wife choose risky jobs; d=2 if the husband chooses a risky job and the wife chooses a safe job; d=3 if the husband chooses a risky job and the wife chooses non-work; all the way up to d=7 if the husband chooses non-work and the wife chooses a risky job; d=8 if the husband chooses non-work and the wife chooses a safe job; and d=9 if the husband and the wife choose non-work.

The value function of each case is defined by

$$V_d(\Omega\,;\gamma) = \begin{cases} \max_{a',c,n^m,n^f}\{u(c,n^m,n^f;\gamma) + \beta\xi' EV[(\Omega';\gamma)|\Omega,\gamma,d]\} \;\; if\ j < j_R \\ \max_{a',c}\{u(c;\gamma) + \beta\xi' EV[(\Omega';\gamma)|\Omega,\gamma]\} \;\; if\ j_R \le j < j_T \\ \max_{c}\ u(c;\gamma) \;\; if\ j = j_T \end{cases}, \tag{9}$$

subject to

$$c + \xi' a' = [1 + (1-\tau_k)r]a + (1-\tau_n)\sum_{g\in\{m,f\}} p^g \varepsilon^{g,n}(j,\eta^{g,n},\epsilon^{g,n};\gamma)n^g + \mathrm{I}_{j\ge j_R} b(1-\tau_n),$$
$$0 \le n^g \le 1,\;\; c \ge 0,\;\; a' \ge \underline{a}, \tag{10}$$
$$b = 0\;\; if\;\; j < J_R\,,$$

where β represents the discount factor; b is a lump-sum transfer taxed at τ_n; and $\varepsilon^{g,n}$ is the gender-job-specific efficiency unit of labor, which consists of both deterministic and stochastic components of wages.

f) Recursive stationary equilibrium

Individual households are born with heterogeneous risk preferences indexed by γ which changes with age: the older the more risk-averse. Let $S_\Omega \equiv \mathcal{A} \times \mathcal{J} \times \boldsymbol{\mathcal{H}^m} \times \boldsymbol{\mathcal{H}^f} \times \boldsymbol{\mathcal{E}^m} \times \boldsymbol{\mathcal{E}^f}$ be the state space, $B(S_\Omega)$ be the Borel sigma algebra on S_Ω, and $(S_\Omega, B(S_\Omega))$ be the measurable space, respectively. The probability measure of household over the measure space is μ, which is consistent with household behavior. Then, a recursive stationary equilibrium is a collection of decision rules, $\{c(\Omega\,;\gamma,d), a'(\Omega\,;\gamma,d), n^m(\Omega\,;\gamma,d), n^f(\Omega\,;\gamma,d)\}$; endogenous shares of households choosing different types of jobs and labor market participation, $\{s^1, s^2, \dots,, s^9\}$; value functions, $\{V(\Omega\,;\gamma,d)\}$; prices, $\{r,p^m,p^f\}$; aggregate capital, K; aggregate gender-specific labor inputs, $\{H^m,H^f\}$; government spending, G; and stationary distribution $\mu(\Omega\,;\gamma,d)$ such that

1. The decision rules and value functions solve the household problem.
2. $\sum_{d=1}^{9} s^d = 1$ $(s^d = \int_{S_\Omega, I_d=1} d\mu(\Omega\,;\gamma,d))$
3. Factor prices are determined competitively:

$$r = \alpha Z\left(\frac{H}{K}\right)^{1-\alpha} - \delta,\ p^m = \lambda(1-\alpha)\left(\frac{K}{H}\right)^{\alpha},\ p^f = (1-\lambda)(1-\alpha)\left(\frac{K}{H}\right)^{\alpha}, \qquad (11)$$

where $H = [\lambda(H^m)^\theta + (1-\lambda)(H^f)^\theta]^{1/\theta}$.

4. Markets clear:

(1) $H^g = \sum_{d=1}^{D} H_d^g$, *where* $H_d^g =$

$$\int_{S_\Omega\times\Gamma, I_g=1, I_d=1} \varepsilon^g\left(j,\eta^g,\epsilon^g;\gamma,d\right) n^g(\Omega\,;\gamma,d)\,d\mu(\Omega\,;\gamma,d) \text{ for } g\in\{m,f\}, \qquad (12)$$

(2) $K = \sum_{d=1}^{D} \int_{S_\Omega\times\Gamma, I_d=1} a(\Omega\,;\gamma,d)\,d\mu(\Omega\,;\gamma,d),$ (13)

(3) $C + K' + G = ZK^\alpha H^{1-\alpha} + (1-\delta)K,$ (14)

where $C = \sum_{d=1}^{D} \int_{S_\Omega\times\Gamma, I_d=1} c(\Omega\,;\gamma,d)\,d\mu(\Omega\,;\gamma,d)$ is aggregate consumption.

5. The government budget constraint is satisfied:

$$G + (1-\tau_n) b \sum_{d=1}^{D} \int_{S_\Omega\times\Gamma, j\geq j_R, I_d=1} d\mu(\Omega\,;\gamma,d) =$$

$$\tau_k r \sum_{d=1}^{D} \int_{S_\Omega\times\Gamma, I_d=1} a((\Omega\,;\gamma,d)\,d\mu(\Omega\,;\gamma,d) + \tau_n(p^m H^m + p^f H^f). \qquad (15)$$

6. The stationary distribution satisfies

$$\mu'(\boldsymbol{S_\Omega};\gamma,d) = \sum_{d=1}^{D} \int_{S_\Omega\times\Gamma, I_d=1} Q(\Omega,\boldsymbol{S_\Omega})\,d\mu(\Omega\,;\gamma,d) \text{ for all } \gamma\in\Gamma, \qquad (16)$$

where $\boldsymbol{S_\Omega} \equiv (\mathbf{A}\times\mathbf{J}\times\mathbf{H^m}\times\mathbf{H^f}\times\mathbf{E^m}\times\mathbf{E^f})$ is the typical subset in $B(S_\Omega)$, and $Q(\Omega,\boldsymbol{S_\Omega})$ is the transition function such that

$$Q(\Omega,\boldsymbol{S_\Omega}) = I_{\{j+1\in\boldsymbol{J},\ a'(\Omega;\gamma,\mathrm{d})\in\boldsymbol{A}\}} Pr\{(\eta^m)'\in\boldsymbol{H^m}, (\eta^f)'\in\boldsymbol{H^f}, (\epsilon^m)'\in\boldsymbol{E^m}, (\epsilon^f)'\in$$

$$\boldsymbol{E^f} \mid \eta^m,\eta^f,\epsilon^m,\epsilon^f)\ \xi.$$

2. Alternative Model

The alternative model assumes homogenous risk preferences and only one type of job in terms of wage risk, which trivializes the workers' job (risk) selection process. Otherwise, the model set-up and assumptions remain identical between the two models.

IV. Determination of Model Parameters

1. Externally determined model parameters

The externally determined model parameters are set commonly in both the baseline and alternative models with the exception of the distribution of risk preferences and job-specific wage-shock profiles. They are summarized in Table 1.

a) Demography

We assume that households start their economic activities at age 1, which represents an actual age of 25. They work for forty years, retire at age 41 (actual age of 65), and die at age 61 (actual age of 85). Survival probabilities are obtained from the Vital Statistics of the United States for 1972 and 2004 for the 1970s and the 2000s, respectively.

b) Technology

For the 1970s and the 2000s, respectively, the capital's share of income, α, is set to 0.31 and 0.34; the total factor productivity, Z, is set to 0.88 and 1; and the depreciation rate of capital, δ, is set to 0.062 and 0.067, which are provided by the *Bureau of Economic Analysis*. Each pair of values represent annual averages within periods of 1970-1974 and 2002-2006, respectively. The parameter governing the substitutability between male and female labor inputs, θ, is assumed to be 1 for both periods (perfect substitutes).

c) Tax

According to the *Economic Report of the President*, the tax rate on labor income, τ_n, increased from 0.28 in the early 1970s (annual average of 1970-1974) to 0.31 in the 2000s (annual average of 2002-2006). In contrast, the tax rate on capital income, τ_k, was reduced from 0.35 to 0.26.

d) Preferences

In the period utility function, the parameters, σ_m , σ_f, which regulate the Frisch elasticity of labor supply for males and females, respectively, are set to 2.08 and 0.57 for the 1970s, and 2.08 and 0.80 for the 2000s, respectively.[12] Consequently, female labor supply is less elastic in the 2000s relative to the early 1970s.

The current analysis focuses on the role of individual heterogeneity in risk preferences (and self-selection into risky sectors) in the welfare analysis of rising wage volatility. For the heterogeneous economy, we use the values of risk aversions by individual and age that are estimated by Light and Ahn (2010). They use the income-gambling questions addressed to the NLSY 79 respondents and form four ordinal ranking categories based on respondents' direct responses to the questions. Then, they conduct the maximum likelihood estimation which finds the parameter values of the model that maximize the probability of those four categories being observed (for details of the procedure, see p.917 of their paper).[13]

In principle, our analysis could allow individual risk preferences to vary over the life-cycle. With age-varying risk preferences, however, the value function becomes discontinuous over the life-cycle, and the global concavity is not guaranteed. We, therefore, take the average γ value over the life-cycle, and allow heterogeneity in age-fixed individual-specific (innate) risk preferences in the model. Basic steps are as follows. First, for each individual, we apply the Ordinary Least Squares (OLS) estimation to the following equation:

$$ln\,\gamma_{i,t} = \alpha_1 + \alpha_2 j_{i,t} + \alpha_3 j_{i,t}^2 + u_{i,t}, \tag{17}$$

where $\gamma_{i,t}$ is the relative risk aversion of individual i at t, $j_{i,t}$ is age of the individual at t, and $u_{i,i}$ is the error term. The results show that individuals are heterogeneous not only in the initial value

[12] We borrow the parameter values from Heathcote et al. (2010) whose model generates Frisch elasticity of labor supply of 0.48 for males for 1967-2005; 1.77 for females in 1967 and 1.25 in 2005. Using these values, Heathcote et al. (2010) replicate some important empirical facts on the ratio of average female to average male hours and the correlation between year-to-year growth rates of a husband's and a wife's wages. Also, these values are consistent with empirical evidence from micro econometric analysis. See Reichling and Whalen (2012) for a review of estimates of the Frisch elasticity of labor supply.

[13] This estimation methodology is typical in the literature. See, among others, Ciappori and Paiella (2011), Cozzi (2015), Kimball et al. (2008, 2009), and Sahm (2007) for studies that use similar estimation methods.

(at 25)[14] but also in the growth rate of the γ value.[15] Then, for each individual, predicted values are averaged over the 25-64 stages of the life-cycle where most important economic decisions are made. The results show that the estimated parameters of individual relative risk aversions are log normally distributed with the mean 5.62.[16]

Comparison with existing studies of the degree of risk aversion is in order. Aforementioned studies based on the PSID and the HRS consistently find that estimated risk aversions are log-normally distributed.[17] Figure 2 displays the empirical distribution of the estimated relative risk aversion parameters obtained from the NLSY 79. The shape of the distribution appears consistent with the ones of existing studies. Precisely, $\gamma \sim lnN(1.33,\ 0.89^2\ )$. The mean and the median of the measured risk aversion are 5.62 and 3.78, respectively. These values are also similar in magnitudes to those found in aforementioned micro-data-based studies. These values are, however, at odds with those commonly adopted in the consumption literature, where estimates of relative risk aversion are commonly set between 1 and 2. For example, with the reciprocal of the degree of risk aversion $(1/\gamma)$ viewed as the elasticity of intertemporal substitution (EIS), Attanasio and Weber (1993, 1995) find a high elasticity (as high as .8). Heathcote et al. (2010) also assume 1.5 of the mean risk aversion in their model (so about 0.67 of EIS). On the contrary, on the basis of the (log-linearized) Euler equation, an influential work by Hall (1988) finds that the magnitude of EIS is very small (less than .1), implying a mean risk aversion of greater than 10. Two points are worth noting at this stage. First, unlike the consumption literature, the current study adopts the magnitudes and the distribution of risk aversions that are directly measured by actual micro data. Second, as will be revealed in subsequent discussions, the current model with a high magnitude of

[14] The empirical distribution of the measured risk aversions at age 25 turns out to be log normally distributed with the mean and variance of the variable's logarithm being 0.58 and 0.144, respectively.

[15] Applying the OLS to equation (17) based on all individuals in the sample produces the estimated value of α_1 at 0.5313 (standard error estimate=.0049), α_2 at .0441 (.0004), and α_3 at -.00019 (.000007). On average, individuals become more risk-averse as they age, with the marginal propensity to become risk-averse diminishes.

[16] Light and Ahn (2010) and Sahm (2012) show that females are more risk-averse than males. The current paper, however, does not consider gender-differences in risk aversion, as information on individual risk aversion is available only for the respondents, not their spouses. It is believed that risk taking behaviors among female workers, for example, are different in the presence of their spouses. Alternatively, we pool males and females and estimate the average risk aversion for a couple in the household.

[17] As an exception, Cozzi (2015) tries two different specifications of the distribution shape, log-normal and beta distributions. He finds that a *Beta* specification proves to be an excellent solution to his GMM estimation. Also using the Italian panel data (SHIW), Chiappori and Paiella (2011) reject both normality and log-normality of the distribution.

mean risk aversion matches various aggregate properties (e.g., per capita employment, income inequality, capital-output ratio) well in both heterogeneous and homogeneous economies.

Finally, for the homogeneous economy, everyone is assumed to have the same degree of risk aversion as the mean 5.62.

e) Endowment

One important ingredient of the current life-cycle model is the job-specific permanent and transitory wage shock profiles and the persistency of permanent shocks each individual faces over the course of her/his work career. Since there is no job selection process in the homogeneous economy, determination of these parameters is straightforward: job-specific shock profiles are identical to the life-cycle profiles experienced by the entire population. Using the NLSY79, we first estimate the following wage equation for each gender:

$$ln\, w_{i,j,t} = \beta_0 + \beta_1 e_i + \beta_2' D_t + \beta_3 j_{i,t} + \beta_4 j_{i,t}^2 + z_{i,j,t}, \tag{18}$$

where e_i is the education level of individual i, D_t is the time dummy variable, $j_{i,t}$ is the age of individual i in year t, and $z_{i,j,t}$ represents the stochastic wage component. Then, using the Ordinary Least Squares (OLS) residuals from equation (18), we apply a Generalized Method of Moments (GMM) estimation to equation (6) for each gender, and estimate variances of permanent and transitory shocks and the persistency of permanent shocks at each age of the life-cycle (see Appendix 2 for details). Finally, the life-cycle profile is smoothed based on the Hodrick-Prescott filter (smoothing parameter=100) for each type of shock and by gender, and then a polynomial function is adapted to the smoothed series.[18]

The lower part of the penultimate column of Table 1 reports estimated life-cycle shock profiles for the 1970s, and Figure 3 visualizes these profiles by the four solid lines.[19] Life-cycle

[18] As will be explained subsequently, the last step is to reduce the number of structural parameters to be estimated in the heterogeneous economy, and derive comparable estimates for the homogeneous economy. It is shown that, for each of the four types of wage shocks, more than 99% of the variation of the HP filtered series over the life-cycle is explained by an appropriate polynomial specification.

[19] Various model selection criteria conclude that permanent wage shock profiles, males or females, are U-shaped, while transitory ones are mildly W-shaped. Precisely, permanent shock profiles are quadratic functions, and transitory shocks are polynomial functions of degree four over the life-cycle, with all the coefficients being statistically significant and the leading coefficient being positive in each case.

permanent shock profiles are U-shaped for both genders, which shows individuals experience larger shocks in the earlier and later stages of the life-cycle, compared to the middle stage. Although life-cycle transitory shock profiles do not show a clear U-shaped pattern, they are also greater in the earlier and later, relative to the middle stages of the life-cycle.[20] Both permanent and transitory shocks are generally greater for females than males for most of the work career.

To derive the life-cycle wage shock profiles for the 2000s, we shift the four life-cycle profiles of the early 1970s by differences between 2002-2006 and 1970-1974 in the average variance of the four types of wage shocks that appear in Figure 1. They are reported in the last column of Table 1. As there exists only one type of job in the homogeneous economy, all of these observed profiles are also regarded as 'job-specific' wage shock profiles. As shown in the penultimate row of Table 1, permanent shocks are slightly more persistent for males than females (0.963 vs. 0.947). Finally, following Hyslop (2001), correlations between spouses' wage shocks are set at 0.57 and 0.15 for permanent and transitory shocks, respectively. We assume the same correlations in the heterogeneous economy for both the risky and safe sector.

2. Model estimation and internally determined model parameters

   a) Estimation strategy

The remaining model parameters are internally determined in the process of estimating the model. They include the share of male labor among the total labor input, gender-specific disutility of work, discount factor, borrowing limit, and retirement benefit. These are common structural parameters in both the baseline and alternative models. For the baseline model (heterogeneous economy), job-specific shock profiles are additionally estimated by gender. Identification of job-specific shock profiles is tricky in the heterogeneous economy, where not only do individuals have heterogeneous risk preferences, but jobs are also heterogeneous with respect to their associated wage risks. A required input of the baseline model is the job-specific permanent and transitory shock profiles (along with the persistency of permanent shocks) an individual would expect over the course of the life-cycle if she/he is randomly assigned to a risky or a safe job. These structural parameters are not directly observed in most survey-based individual data as wage shock profiles

[20] Using the PSID, 1967-1997, Karahan and Ozkan (2013) estimate life-cycle profiles of permanent and transitory shocks for male household heads. Their permanent shock profile is very similar to ours for males. While their transitory profile appears slowly increasing with age, ours is mildly W-shaped.

are possibly different between risky and safe jobs, and workers self-select into jobs in the process of maximizing their life-cycle expected utility. Our strategy is to determine these structural parameter values internally by matching the observed wage shock profiles of various risk preference groups with corresponding model-generated profiles.

First, it would be quite a challenging task to estimate variances of both permanent and transitory shocks at each age of the life-cycle by gender and by job type. Combined with the forty years of the work-cycle, there would be 320 parameters of variances of wage shocks plus four parameters of persistency of permanent shocks. To reduce the number of parameters to be estimated, we adopt a parametric form of the shock profile. We set the gender- and job-specific life-cycle wage shocks (permanent or transitory) as a polynomial function of degree four.

Second, as for the empirical moments that help pin down the coefficients of these polynomial functions, we first split our NLSY79 sample between genders and between two risk preference groups: those whose risk tolerance level (inverse of risk aversion) is within the top 10% of the entire distribution and the rest.[21] Then for each gender and preference group, we estimate the life-cycle shock profiles (both permanent and transitory) using the same method described previously, extract life-cycle shock trends using the HP filter, and then adapt polynomial functions to the smoothed series. Various model selection criteria conclude that, as in the case of the homogeneous economy, all permanent wage shock profiles are quadratic functions (U-shaped), and all transitory shocks are polynomial functions of degree four (mildly W-shaped) over the life-cycle, regardless of genders or job types. In each polynomial function, all the estimated coefficients are statistically significant and the leading coefficient appears positive.

The first column of Table 2 contains 36 empirical moments of the life-cycle wage shock profiles (permanent and transitory) for each gender and preference group of the 1970s economy,[22] along with 9 additional target moments, including average household market hours, ratio of female to male market hours, male per capita employment, female per capita employment, capital-to-output ratio, gender wage gap, negative asset share, U.S. pension system, and the Gini coefficient of income.

[21] This division is based on Jensen and Shore (2011, 2015).

[22] These include four different degrees of persistency of permanent shocks by gender and by preference group: For both genders, permanent wage shocks are less persistent for risk-tolerant individuals relative to risk-averse ones.

Finally, the 42 structural parameters in the baseline model (listed in Table 3) are estimated by the Simulated Method of Moments (SMM, McFadden, 1989), which minimizes the distance between the vector of model parameters and a set of 45 target moments. As previously discussed, life-cycle shock profiles are externally determined in the alternative model (homogeneous model), which does not involve a job selection process. Consequently, only 6 model parameters are internally determined by the SMM that uses 9 empirical moments. (See Appendix 3 for details of the SMM procedure and Appendix 4 for the computation algorithm.)

We follow the same steps to estimate the structural parameters for the 2000s economy, which requires information on life-cycle wage shock profiles for each gender-preference group that are actually experienced by households in the 2000s along with other empirical moments. As before, we could shift the life-cycle profiles of the early 1970s in a parallel fashion by the differences between 2002-2006 and 1970-1974 in the average shock observed in Figure 1. Due to lack of information, however, we cannot determine empirically how changes in (the variance of) wage shocks are distributed between the two preference groups. For this reason and others, most existing studies implicitly assume that all individuals face the same increase in the variance of wage shocks, regardless of which sector they are employed in. This is a distortion of the true nature of the economy, when some jobs/sectors (e.g., information technology, construction) are subject to greater increase in wages shocks than others (e.g., clerical work, services), and when more risk-tolerant workers are more likely to get involved in the former than the latter jobs. In fact, Jensen and Shore (2011, 2015) find that most of the recent increase in income volatility is mainly attributed to the increase in volatility at the right tail, especially at the top 10% of the distribution of income shocks. Other things being equal, the assumption of an equal increase in wage shocks between risk-tolerant and risk-averse groups would exaggerate the measured welfare cost of the increased wage shocks, considering workers' endogenous sorting into risky or safe jobs.

We investigate two polar cases. Following the typical convention, we first assume that both risk-tolerant and risk-averse groups experience the same increase in (the variance of) wage shocks in the 2000s relative to the early 1970s (henceforth Case A). Following the spirit of Jensen and Shore (2011, 2015), we deal with another polar case (Case B) that only the risk-tolerant group experiences wage shock increases. This is done by shifting the 1970s' life-cycle wage shock profiles of risk-tolerant groups by a larger scale than what is applied in Case A, leaving the profiles of risk-averse groups unchanged at the 1970s level. To determine the scale of the shift, at each stage of the life-cycle, we divide the amount of the increased wage shock, permanent or transitory, observed in the homogeneous economy by the employment share of the risk-tolerant group (0.1). (See Appendix 5 for details of the derivation of observed life-cycle wage shock profiles by preference group for the 1970s and 2000s economies.) Obviously, the actual distribution of the increased wage shocks among different preference groups is located between the above two polar cases. The welfare cost associated with the increased wage shocks would also be bounded by these cases.

b) Estimation results

Comparison of the empirical moments and model-generated moments in Table 2 concludes that the current models match the data moments to a reasonable degree in both the heterogeneous or homogeneous economies. Estimated structural parameters are presented in Table 3. The numbers in parentheses are the estimated standard errors obtained by the SMM estimation and they suggest that all parameters are estimated precisely.

On the basis of the estimates in Table 3, Figures 3 visualizes, for the 1970s economy, how one would expect permanent and transitory wage shocks over the course of a work career when she/he is involved in the risky (the dashed line) or safe (the line connecting circular data points) sector. Panels (a) and (b) are for men, and panels for (c) and (d) are for women. As explained previously, in each panel, a solid line represents the profile of wage shocks in the homogeneous economy which has only one type of job. As expected, in each panel, the life-cycle shock profile in the safe (risky) sector is located below (above) that in the homogeneous economy. With higher estimated variances in risky jobs relative to safe jobs, expected wages (in levels) are higher in the former than in the latter jobs, other things being held constant.[23]

Lastly, for Case A, Figure 4 visualizes how sector-specific wage shock profiles, both permanent and transitory, have changed in each gender-sector category from the early 1970s to the 2000s.[24] Thicker and thinner lines are for permanent and transitory shocks, respectively, and solid and dashed lines are for the early 1970s and the 2000s. Except for female transitory shocks, life-

[23] For example, in the early 1970s, the simple averages of estimated variances of male permanent shocks over the life-cycle are 0.0297 and 0.0152 in the risky and safe jobs, respectively. Comparable figures for male transitory shocks are 0.0349 and 0.0185. Similar patterns are observed for female shocks, permanent and transitory, and also for the 2000s.

[24] Corresponding graphs for Case B are available upon request.

cycle wage shock profiles have shifted upward in the 2000s compared to the early 1970s in both risky and safe sectors.

V. Welfare Consequences of Changing Wage Shocks

On the basis of the estimated models in Section IV, this section evaluates the welfare costs of the changing wage shocks from the early 1970s to the 2000s. We start with the estimated models for the 1970s. Our central research question is how much welfare loss/gain the 1970s households would experience if they faced the wage shocks of the 2000s, with all the other economic conditions (including output and input prices) remaining the same at the 1970s level. For robustness checks of the results, however, later discussions include general equilibrium effects and/or changing other economic conditions in the welfare analysis. Obviously, the 1970s households would pay higher welfare costs if they had myopic beliefs about future changes in wage shocks, compared to the case when they foresaw the 2000s wage shocks perfectly. As it turns out, however, all of the following analytical results remain qualitatively similar regardless of the households' ability to foresee the future changes. Our analyses in subsections 2 through 4 are based on the perfect foresight model, whereas subsection 5 discusses the case of 'surprise shocks.'

1. Welfare Cost Calculations

For each household, the welfare costs of the changing wage shocks are the values of $\boldsymbol{\omega}$ and $\boldsymbol{\omega}'$ in the heterogeneous and homogeneous economies, respectively, which solve the following equations (see Heathcote et al. (2010), among others, for a reference):

$$E\left(\sum_{j=1}^{J_T} \beta^j \phi_j u(c_{ij}^*, n_{ij}^{m*}, n_{ij}^{f*}; \gamma_i\right) = E\left(\sum_{j=1}^{J_T} \beta^j \phi_j u((1+\boldsymbol{\omega})c_{ij}^{**}, n_{ij}^{m**}, n_{ij}^{f**}; \gamma_i\right),$$

$$E\left(\sum_{j=1}^{J_T} \beta^j \phi_j u(c_{ij}^*, n_{ij}^{m*}, n_{ij}^{f*}\right) = E\left(\sum_{j=1}^{J_T} \beta^j \phi_j u((1+\boldsymbol{\omega}')c_{ij}^{**}, n_{ij}^{m**}, n_{i,j}^{f**}\right), \quad (19)$$

where $\{ c_{ij}^*, n_{ij}^{m*}, n_{ij}^{f*}\}_{j=1}^{j_T}$ and $\{ c_{ij}^{**}, n_{ij}^{m**}, n_{ij}^{f**}\}_{j=1}^{j_T}$ are the equilibrium allocations of a household facing the 1970s and the 2000s wage shocks, respectively. Then, measured welfare costs are averaged across all households to produce the welfare costs of the observed changes in wage shocks.

2. Case A: Everyone is subject to the same increase in the variance of wage shocks

   a) Effects of workers' risk choice in welfare evaluation of changing wage shocks

In Case A, we implement the same increase in the variance of wage shocks to all simulated households regardless of their risk preferences. Table 4 compares measured welfare costs between the homogeneous and heterogeneous economies that are generated by all four types of shocks (male permanent, male transitory, female permanent, and female transitory) and by each shock individually. In calculating the welfare costs of the changing wage shocks, we leave all the other parameter values/economic conditions at the previous level (1970s). Until a later discussion, we do not allow the general equilibrium (GE) effects by fixing the output and input prices at the early 1970s level and focus on the partial effects of the rising wage uncertainty. We do allow households to adjust their family labor supply and borrowing/saving in response to the increased wage shocks.

Several findings emerge immediately from Table 4. First and most importantly, welfare costs are overstated by assuming homogeneous risk preferences and therefore, neglecting workers' self-selection into risky/safe jobs. For example, when the 1970s households face the four types of wage shocks that are experienced by the 2000s households, the measured welfare cost is 14.13% and 8.47% (in life-time consumption equivalent) in the homogeneous and heterogeneous economies, respectively.[25] Figures in the last column suggest that the welfare cost is overstated by about 70% in the homogeneous, relative to heterogeneous, economy.

Second, in both economies, the increase in male permanent shock is a dominant contributor to the overall welfare cost. Even though permanent shocks increased similarly for both genders, the welfare cost caused by the increased female permanent shock is about a half of the amount generated by the increased male permanent shock. This is mainly attributed to women's lower

[25] Typically, existing studies assumed homogeneity in risk preferences in evaluating the welfare consequences of rising income/earnings shocks during the 1980s and the 1990s, and found smaller estimates of the welfare costs than the current one. First, the degree of risk aversion adopted in the current study is higher than those in existing studies. Second, the current study focuses on the rising wage volatility since the early 1970s, which differs in the magnitude and the nature from the rising earnings inequality since the 1980s. That said, the current study focuses on comparison of measured welfare costs between the two economies and across different types of shocks and evaluation of effectiveness of insurance measures within the same analytical framework, i.e., the same degree of average risk aversion and the same sample period.

wages and hours, and consequently, women's smaller contribution to the household income. Although male transitory shocks increased by a larger extent than male permanent shocks, the resulting welfare cost is much smaller for the former than the latter. As expected, permanent shocks are even more consequential than transitory shocks. Little welfare gain is generated by the reduced female transitory shock.

Third, in each economy, although the total welfare cost is greater when all four types of shocks come together, relative to the sum of four measured welfare costs that would be generated by the four types of shocks that occur one at a time (14.13% vs. 13.36% in the homogeneous economy, and 8.47% vs. 7.61% in the heterogeneous economy)[26], the difference is relatively small, implying that the four types of shocks are roughly additive in generating the welfare cost with little interactive effect.

b) Effectiveness of insurance measures

In the previous analysis, households are able to adjust family labor supply and borrowing/saving in response to the increased wage shocks. Obviously, the measured welfare cost would be even greater without these insurance mechanisms. To examine the effectiveness of each of these insurance mechanisms, we re-estimate the welfare cost without allowing the simulated households to adjust their actions to the rising wage shocks. This is done by fixing the households' labor supply and/or borrowing/saving at their 1970s levels.

Table 5 compares effectiveness of insurance mechanisms between family labor supply adjustment and borrowing/saving and between the homogeneous and heterogeneous economies. Estimates in the first two columns are imported from Table 4, representing the welfare costs estimated with all insurance measures used by households. In columns 3 and 4, we re-compute the welfare costs with only the family labor supply fixed at the early 1970s level. In columns 5 and 6, we redo the analysis with only borrowing and saving fixed at the early 1970s level. Then, we fix both measures at the early 1970s level, estimate the welfare costs, and report the results in columns 7 and 8. Numbers in parentheses represent the additional welfare costs of not using either family labor supply or borrowing/saving or both, relative to the case of using both mechanisms. For

[26] This observation, if any, is attributed to two factors. First, due to the nature of individual risk aversion, the welfare cost is a convex function of the size of the increased wage shock. Second, due to imperfect insurability, the welfare loss becomes greater when all shocks come together, compared to case they come one at a time.

example, in the heterogeneous economy, an additional 4.40 percentage points (=12.87%-8.47%) of the welfare cost is associated with not being able to adjust family labor to changes in the four types of wage shocks. Numbers in brackets stand for additional welfare gains of using either or both measures, relative to the case of no adjustment in any insurance mechanism. For example, focusing on the heterogeneous economy, allowing the 1970s households to adjust only family labor supply to changes in the four types of wage shocks (estimate in column 6) creates an additional welfare gain of 2.90 percentage points (=14.98%-12.08%).

Several important findings emerge from Table 5. First, in all cases, assuming homogeneity in risk preferences and neglecting self-choice of risk exaggerates the welfare costs of the changing wage shocks, confirming our previous finding in Table 4. Overstatement of the welfare cost by the representative worker-job model is independent of the availability of insurance measures. The extent of 'bias' is quite robust with respect to the types of shocks and/or the states of different insurance measures adopted. Our calculation shows that, on average, the estimated welfare cost is about 1.7 times greater in the homogeneous economy than in heterogeneous economy, with little variation in the ratio across different cases in Table 5. The results imply that all of the following observations are preserved in a qualitative sense even in the homogeneous economy which is frequently adopted in existing studies. The following discussions focus on the heterogeneous economy, which is our preferred model.

Second, family labor supply adjustments are somewhat more effective than borrowing and saving in mitigating the welfare cost caused by changes in the four types of wage shocks, as evidenced by the greater welfare gain (or greater reduction in the welfare cost) from adjusting family labor supply than from borrowing and saving.

Third, more interestingly, the two insurance mechanisms are complementary in mitigating the increased wage shocks. For example, when the economy is hit by four types of wage shock changes, 6.51 percentage points of additional welfare cost is associated with not using any insurance measure, relative to the case of allowing both insurance mechanisms. Put differently, the same percentage points of welfare gain is created by allowing the early 1970s households to adjust both family labor supply and borrowing/saving to the changed wage shocks. (Readers may verify that the number in the parenthesis of column 8 is identical to the one in the bracket of column 2.) Of the total welfare gain (6.51 percentage points), the 'direct' effect of family labor supply adjustment is 2.90 percentage points, as shown in the bracket of column 6. In contrast, the borrowing and saving behavior alone creates 2.11 percentage points of the welfare gain, as revealed in the bracket of column 4. The sum of these two direct effects amounts to 5.01 percentage points, and the difference between the total gain (6.51 percentage points) and the sum of the two direct effects (5.01 percentage points) is called an 'indirect' or 'interactive' effect, which is 1.50 percentage points, as shown in the last column. Alternatively, these 1.50 percentage points of the indirect effect can be obtained by adding the two additional welfare costs (4.40 percentage points and 3.61 percentage points) of fixing the two measures one by one at the 1970s level (as shown in the parentheses of columns 4 and 6) and subtracting the additional welfare cost of not using any insurance mechanism (6.51 percentage points) from the sum (8.01 percentage points). Obviously, the total welfare gain of allowing family labor supply adjustments (4.4 percentage points), which is the sum of direct and indirect welfare gains (2.9 percentage points+1.5 percentage points), is also greater than that of the borrowing and saving adjustment (3.61 percentage points =2.11+1.5). That joint introduction of the two measures creates additional welfare gains of 1.5 percentage points (or the insurance effect of each measure is greater when the other measure is allowed to be adjusted), which is qualitatively consistent with Attanasio et al.'s (2005) finding of complementarity of the two measures.

Fourth, the relative effectiveness of an insurance measure is different depending on the type of shock under consideration. While family labor supply adjustment is more effective in reducing the welfare costs caused by permanent wage shocks,[27] male or female, (male) transitory shocks are effectively reduced by borrowing and saving behaviors, not by the labor supply behavior. For example, when only family labor supply (borrowing/saving) is allowed to be adjusted in the state where both measures are fixed at the early 1970s level, the welfare cost caused by the increased male permanent shock is reduced from 8.22% to 6.32% (7.19%), producing 1.90 percentage points (1.03 percentage points) of additional welfare gain. In contrast, the welfare cost of the increased male transitory shock is reduced from 2.17% to 2.02% and 1.51% when family labor supply and borrowing/saving are adjusted to the increased shock, resulting in an additional welfare gain of 0.04 percentage points and 0.66 percentage points, respectively.

a) Details on effectiveness of family labor supply adjustments

[27] See Blundell et al. (2016) for a similar finding.

In Table 5, we analyze the effects of family labor adjustments as a whole without distinguishing an individual's own labor supply adjustment from their spouse's labor supply adjustment. To understand how labor supply adjustments are jointly made within each household, we decompose the total welfare effect of family labor adjustments between the effect of self-adjustment and the 'added' worker effect. We focus on our preferred model that allows heterogeneous workers' self-selection into risky jobs. We analyze only the case of increased permanent shocks, as they are effectively mitigated by family labor supply adjustments.

Table 6 summarizes the results. As in Table 5, we report the results under two scenarios: when borrowing/saving adjustment is allowed so that the effect of family labor adjustment includes both direct and indirect effects (estimates in the first five columns), and when it is not allowed so that only the direct effect of family labor supply adjustment is analyzed (those in the last five columns).[28] It is found that, when households are hit by increased male permanent shocks, added-worker effects by wives play a greater role in mitigating the welfare loss, relative to the effects of husbands' self-labor supply adjustment. With or without the borrowing/saving mechanism, about 60% of the total welfare-improving effect of family labor supply adjustments is explained by the added-worker effect. Still, husbands' labor supply adjustment also plays some role in reducing the welfare loss. Estimates in the second row show that, when households are subject to increased female permanent shocks, added-worker effects by husbands play a greater role in reducing the welfare loss, relative to wives' self-labor supply adjustment. These findings are generally consistent with Blundell et al. (2016) except that the role of husbands' self-labor adjustment appears more significant in the current study than in Blundell et al. when the household faces the increased male permanent shock. For reasons stated previously, however, both estimated 'added-worker' effects by husbands and effects of wives' self-labor supply adjustments are generally smaller, compared to the case when the households are hit by increased male permanent shocks. (It is worth noting that both male and female permanent shocks increased in similar magnitudes during our sample period.)

[28] Readers may verify that, in each scenario, the sum of the added worker effect and the effect of self-labor supply adjustment is identical to the total effect of family labor supply adjustments observed in Table 5. For example, in Table 6, when the household is hit by an increased male permanent shock, the sum of the two effects is 2.72 percentage points and 1.90 percentage points with and without adjustment of borrowing/saving, respectively. These numbers are observed, respectively, in the parenthesis of row 2 and column 4 of Table 5 and the bracket of row 2 and column 6.

In Table 7 we further analyze how wives (husbands) adjust their labor in response to changes in their husbands' (wives) permanent wage shocks. In particular, we decompose the total added-worker effect observed in Table 6 into the extensive and intensive margins of spouses' labor supply adjustments. The upper panel of Table 7 summarizes the results for Case A. First, wives increase their labor in response to the increased husbands' wage shocks by more than the amount of labor supply increase made by husbands in response to their wives' increased wage shocks. For example, we saw from Table 6 that with the borrowing and saving behavior allowed, households are able to reduce the welfare cost caused by the increased male (female) permanent shock by about 1.6 (0.7) percentage points solely by adjusting wives' (husbands') labor supply. As shown in the third column of Table 7, this additional welfare gain comes from wives (husbands) increasing their total hours (employment times average hours) by 9.3% (3.2%). As permanent wage shocks increased by 48% and 45% for males and females, respectively, during our sample period, the elasticity of the wife's labor supply with respect to the husband's permanent wage shock is estimated at 0.194, compared to 0.073 which is the elasticity of husband's labor supply with respect to the wife's wage shock (fourth column).

Second, as expected, the added-worker effect in terms of labor adjustment becomes greater when the borrowing and saving behavior is fixed at the 1970s level. The added-worker effect by wives increases to almost 0.3 in terms of the elasticity of labor supply with respect to their husbands' wage shock. The comparable figure for husbands is about 0.1. Third, and perhaps more interestingly, most of the wife's added-worker effect is explained by the extensive margin. For example, whether or not the borrowing/saving mechanism is available, about three quarters of the wives' total added-worker effect is accounted for by the extensive margin of their labor supply adjustments (estimates in the first four rows). No such pattern exists for the 'added-worker' effect by husbands, as most of husbands are already participating in the labor market.

3. Case B: Only risk-tolerant individuals experience increase in wage shocks

In this subsection, we analyze another polar case of when only the risk-tolerant group suffers from the wage shock increases. Table 8 reports the results. Estimates in the first column of Table 8 are comparable to those in the second column of Table 4, and estimates in columns 2 through 5 correspond to those for the heterogeneous economy in Table 5. First and most importantly, overstatement of the welfare cost by neglecting heterogeneous workers' risk choice appears more apparent in Case B than Case A. For example, the estimated welfare costs associated with changes in the four types of wage shocks are 8.47% and 4.91% in Case A and Case B, respectively. We noted previously that, in Case A, the welfare cost is overstated by about 70% in the homogeneous, relative to heterogeneous, economy. Comparison of estimates in the first columns of Table 4 and Table 8 reveals that, if Case B represents the true state of the world, the estimated welfare cost is almost tripled (14.13/4.91=2.9) by neglecting heterogeneity in risk preferences and workers' risk choice. Our interval estimate of the welfare cost of the changing wage shocks is between 4.91% and 8.47%.

Second, the measured welfare cost remains substantial at 4.9% even in Case B. It should be noted that this significant welfare cost is obtained after heterogeneous households are allowed to choose their own risk level associated with jobs and adjust their family labor supply and borrowing/saving. In addition, households are still assumed to have the ability to foresee perfectly the future changes in wages shocks. Surely, self-insurance mechanisms are not sufficient for absorbing the entirety of the increased wage shocks, though they are functioning well.

Third, all the previous findings shown in Tables 4 and 5 are qualitatively preserved even in Case B. To repeat, the male permanent shock is the dominant contributor to the total welfare cost; family labor supply adjustment contributes more to the reduction of the welfare cost of changes in the four types of wage shocks, compared to borrowing and saving; while the welfare cost caused by permanent shocks, male or female, is more effectively reduced by family labor supply adjustments, the borrowing and saving mechanism is well suited to mitigate the transitory shocks; and the two insurance mechanisms are complementary in reducing the welfare cost of rising wage shocks.

Table 9 reproduces Table 6 under Case B. Again, the previous findings in Table 6 survive this new exercise in a qualitative sense. In Case B, added-worker effects by spouses appear even more important compared to the effects of self-labor adjustment.

The lower panel of Table 7 further decomposes the added-worker effect observed in Table 9 into the extensive and intensive margins of spouses' labor adjustments. All the results for Case A are still valid for Case B in a qualitative sense. Most importantly, both wives and husbands react to changes in their spouses' wage uncertainty, and the added-worker effect by wives is most explained by their extensive margins.

4. Perfect Foresight vs. Myopic Beliefs about Wages Shocks

Up to this point, we have assumed that the 1970s households foresee perfectly how the life-cycle wage shock profiles will change in the 2000s. Alternatively, we examine the case where the 1970s households mistakenly believe that the magnitudes and life-cycle patterns of wage shocks will remain unchanged in the future. This is done by making the 1970s households expect that life-cycle wage shock profiles will remain at the 1970s level, but face the realized wage shocks that are generated under the 2000s wage structure. The true welfare cost will be in between the two polar cases.

Table 10 compares measured welfare costs/gains between the two polar cases in the heterogeneous economy, which is our preferred model. As conjectured, surprising the 1970s households by the higher (2000s) wage shocks than they expect makes the measured welfare cost greater. In Case A (Case B), regardless of the types of wage shocks under consideration, the measured welfare costs are about 1.5 (1.3) times greater in the myopic model than in the perfect foresight one. As the increased shocks are not anticipated, the households are unable to fully utilize their insurance mechanisms. For example, although not reported in a table for brevity, when we reproduce estimates in Table 7 under the assumption of myopic beliefs about the future shocks, the estimated cross-elasticities of labor supply with respect to spouses' wage shocks become much smaller compared to those in Table 7, and in most cases, are close to zero. In Table 7, the greatest elasticity (0.278) is observed in the situation where the household experiences the increased male permanent shock, the borrowing/saving adjustment is not allowed, and all households are subject to the same increase in the variance of wage shocks regardless of their risk preferences (Case A). The comparable figure in the myopic world turns out to be 0.093. Other than that, all the previous findings survive this new exercise in a qualitative sense. Among others, even in the myopic world, the welfare cost is significantly overstated by neglecting heterogeneous workers' risk choice.

5. Consideration of General Equilibrium Effects and Changing Economic Environment

So far, we have analyzed welfare consequences of the increased wage shocks from the early 1970s to the 2000s, under the assumption that prices (r, p^m, p^f) and other economic conditions remain unchanged at the early 1970s level. In Table 11, we investigate how the welfare evaluation changes when these factors are considered in our preferred model. While, for brevity, we deal with the case of perfect foresight, the following results remain valid in a qualitative sense even when the households have myopic beliefs about the future. All the estimates represent the estimated welfare costs generated by changes in the four types of wage shocks. The estimates in the first row are borrowed from our previous analysis. When prices are allowed to change in response to changes in wage shocks (estimates in row 2), the welfare cost of the changing four types of wage shocks remains similar in both cases. The insignificance of the general equilibrium effect is also observed in a different, but related literature. For example, Storesletten et al. (2001) find that welfare gains from removing business cycle variation in idiosyncratic shocks remains similar whether or not the general equilibrium effect is considered. With little general equilibrium effect, the rest of the analysis reverts to the case of fixing input and output prices at the 1970s level.

Economic environments have changed concurrently with the increased wage shocks, including technological changes, gender demand shifts, and changes in tax codes. These changes are also expected to affect households' welfare levels. For example, the rapid growth of information technology not only enhances the average total factor productivity, but it also reduces durability of existing skills and knowledge, which may in turn result in greater wage volatility. Heathcote et al. (2010) find welfare gains as high as 3.1% from skill-biased demand shifts through effective human capital investment, and welfare gains as high as 1.4% from gender-biased demand shifts. Unlike Heathcote et al. (2010), we do not model a human capital investment mechanism, but instead use an increase in TFP as a proxy for technological change.[29] Thus, for the welfare effects of technological change, we replace the externally determined value of TFP of the 1970s by that of the 2000s. Similarly, for the effects of gender-biased demand shifts, we replace the estimated value of λ of the 1970s by that of the 2000s. Similar exercises are conducted using externally determined capital and labor tax rates in Table 1.

Changing economic conditions generally create welfare gains in both cases. Focusing on Case B, for example, allowing the four (aforementioned) economic conditions to vary reduces the

[29] Acemoglu (2002), for example, argues that technological change has been skill-biased, induced by the rapid increase in the supply of skilled workers. The current study, however, considers exogenous skill-neutral technological change in the analysis. Sharma et al. (2007) provide a groundwork for using a change in the total factor productivity as a proxy for skill-biased technological change by finding that the technological progress explains 74% of the average TFP growth for the sample period.

measured welfare cost by about 8.9 percentage points. Consequently, despite the increased wage shocks, a typical household of the 1970s economy would have enjoyed substantial welfare gain due to concurrent changes in various economic conditions. The largest part of the welfare gain comes from the increased TFP.[30] Gender-biased demand shifts also contribute to the reduction of the welfare costs to some degree, although less so compared to the increased TFP. Although not reported for brevity, the reduced capital income tax rate and the increased labor income tax rate make little difference in the measured welfare cost of the increased wage shocks.

VI. Conclusion

Using a general equilibrium model with incomplete markets in which married couples choose their life-cycle labor supply, consumption, and savings, we provide a quantitative assessment of the welfare costs caused by the increased wage risk in the United States from the 1970s to the 2000s. Heterogeneous risk preferences and workers' self-selection into risky jobs along with gender differences in wage dynamics constitute unique features of the model.

The most important finding of the current research is that the welfare cost of the increased wage shocks is significantly exaggerated by neglecting heterogeneity in risk preferences and workers' risk choice.

The estimated welfare cost from our augmented model ranges 4.91% to 12.44%, depending on whether or not the shocks are anticipated and how the increased wage shocks are distributed between risk-tolerant and risk-averse groups. The welfare cost remains substantial at 4.91% even when increases in wage shocks are anticipated, risk tolerant workers absorb the entirety of the increased wage shocks, heterogeneous workers are allowed to self-select into risky jobs, and self-insurance mechanisms are functioning. Obviously, even in this 'idealistic' world, self-insurance mechanisms alone are not sufficient for absorbing the entirety of the increased wage shocks, calling for inter-family insurance mechanisms through the financial and capital markets.

The good news is that most of the other analytical results, including the effectiveness of insurance mechanisms, are robust in a qualitative sense with respect to the underlying assumption about preference heterogeneity, the distribution of the increased wage shocks among preference

[30] Following the increased TFP, price per efficiency unit of labor increased by 0.12 (19%) (from 0.56 to 0.68) and 0.08 (21%) (from 0.35 to 0.43) for males and females, respectively.

groups, and/or the expectation of the wage shock changes. To summarize briefly, among the four types of wage shocks, the increased male permanent shock is the dominant contributor to the total welfare cost. The welfare improving effects are generally greater from family labor supply adjustments than borrowing and saving adjustments. While, compared to borrowing and saving, family labor supply adjustments are more effective in reducing the costs caused by permanent shocks, transitory shocks are more effectively mitigated by borrowing/saving. What interests us more is the finding of complementarity of family labor supply adjustments and borrowing/saving in mitigating the welfare costs: family labor supply adjustments can reduce the welfare costs of the increased permanent shocks more effectively when the borrowing and saving behavior is allowed. Evidence shows that when households are hit by increased male (female) permanent shocks, added-worker effects by wives (husbands) play a greater role in mitigating the welfare loss, relative to the effects of husbands' (wives') self-labor supply adjustment. It is also found that at least three quarters of the wives' 'added-worker' effect in response to the husbands' permanent shocks is accounted for by the extensive margin of wives' labor supply adjustment. These insurance mechanisms stop functioning when the permanent shocks are unanticipated. Lastly, measured welfare costs remain similar whether or not prices are allowed to vary following the increased wage shocks (insignificant general equilibrium effect), and more than 100% of the total welfare cost is offset by the welfare gain generated by the concurrent increase in the total factor productivity.

Current findings suggest that labor and credit/financial market policies should be interacted to effectively reduce the welfare loss of households caused by the increased wage uncertainty. The result that wives increase their labor market participation substantially in response to husbands' anticipated permanent wage shocks suggests that policies to enhance the predictability of permanent wage shocks, such as lengthening the advance notice period of mass layoffs, could be welfare-improving.

Table 1. Summary of Externally Determined Parameters

Parameter	Name (Source)	1970s	2000s
(Demography)			
j_R	Age of Retirement (assumption)	41	41
j_T	Terminal Age (assumption)	60	60
$\{\xi\}$	Conditional survival probability (U.S. Life Tables, Centers for Disease Control and Prevention, 1972, 2004)	see text	See text
(Technology)			
α	Capital's share of income (Bureau of Economic Analysis, 1970-74, 2002-06)	.31	.34
Z	Total factor productivity (Bureau of Economic Analysis, 1970-74, 2002-06)	.88	1
δ	Depreciation rate (Bureau of Economic Analysis, 1970-74, 2002-06)	.062	.067
θ	Elasticity of substitution between male and female labor inputs (assumption)	1	1
(Tax)			
τ_n	Labor income tax rate (Economic Report of the President, 1970-74, 2002-06	.28	.31
τ_k	Capital income tax rate (Economic Report of the President, 1970-74, 2002-06)	.35	.26
(Preferences)			
$\sigma_m,\ \sigma_f$	Frisch elasticity of labor supply parameters, male/female (Heathcote et al., 2010)	2.08/.57	2.08/.80
γ_i for heterogeneous	Risk preferences (NLSY79, see text)	$lnN(1.33, 0.89^2)$	
γ for homogeneous	Mean of γ_i's (NLSY79, see text)	5.62	
(Endowment)			
$f^g(j)$	Deterministic wages (PSID, NLSY, see text)	See text	See text
$\rho^g, (\sigma_{\eta_j}^g)^2, (\sigma_{\epsilon_j}^g)^2$ for homogeneous: Life-cycle profile of male permanent	Stochastic wages (PSID, NLSY, see text). Estimated coefficients of polynomial functions fitted to H-P filtered life-cycle series of permanent and transitory shocks.	.01971 -.0009151 0.00002908	.02751 -.0009151 0.00002908
Life-cycle profile of male transitory		.04361 -.00798 .000750 -.00002663 3.21e-7	.07241 -.00798 .000750 -.00002663 3.21e-7
Life-cycle profile of female permanent		.02320 -.0009076 .00002395	.0310 -.0009076 .00002395
Life-cycle profile of female transitory		.08881 -.00316 .00022165 -0.00000971 1.47e-7	.07881 -.00316 .00022165 -0.00000971 1.47e-7
Persistency		ρ^m=.963, ρ^f=.947	
$\rho_p,\ \rho_t$	Correlation between couple's wage shocks (Hyslop, 2001)	.57, .15	

Table 2. Data Generated Moments vs Model Generated Moments

<table>
<tr><th rowspan="3"></th><th colspan="3">1970s</th><th colspan="5">2000s</th></tr>
<tr><th rowspan="2">Data</th><th rowspan="2">Hetero</th><th rowspan="2">Homo</th><th colspan="2">Data</th><th colspan="2">Hetero</th><th rowspan="2">Homo</th></tr>
<tr><th>Case A</th><th>Case B</th><th>Case A</th><th>Case B</th></tr>
<tr><td>Average household mkt hours</td><td>0.229</td><td>0.230</td><td>0.229</td><td colspan="2">0.266</td><td>0.262</td><td>0.261</td><td>0.264</td></tr>
<tr><td>Ratio of female to male mkt hours</td><td>0.373</td><td>0.404</td><td>0.372</td><td colspan="2">0.687</td><td>0.700</td><td>0.690</td><td>0.695</td></tr>
<tr><td>Male per capita employment</td><td>0.896</td><td>0.901</td><td>0.900</td><td colspan="2">0.852</td><td>0.845</td><td>0.853</td><td>0.857</td></tr>
<tr><td>Female per capita employment</td><td>0.431</td><td>0.427</td><td>0.429</td><td colspan="2">0.675</td><td>0.676</td><td>0.667</td><td>0.673</td></tr>
<tr><td>Capital-to-output ratio</td><td>3</td><td>2.99</td><td>2.98</td><td colspan="2">3.2</td><td>3.23</td><td>3.18</td><td>3.15</td></tr>
<tr><td>Gender wage gap</td><td>0.578</td><td>0.569</td><td>0.577</td><td colspan="2">0.760</td><td>0.768</td><td>0.753</td><td>0.755</td></tr>
<tr><td>Negative asset share (Wolff, 2000; Heathcote et al., 2010)</td><td>0.155</td><td>0.151</td><td>0.167</td><td colspan="2">0.155</td><td>0.167</td><td>0.143</td><td>0.155</td></tr>
<tr><td>Redistribution of lifetime earnings (Census, 1972, 2004)</td><td>U.S. pension system</td><td colspan="2">See text</td><td colspan="2">U.S. pension system</td><td colspan="3">See text</td></tr>
<tr><td>Gini coefficient of income</td><td>0.397</td><td>0.427</td><td>0.407</td><td colspan="2">0.466</td><td>0.514</td><td>0.501</td><td>0.496</td></tr>
<tr><td>Life-cycle permanent shock profile of male risk-tolerant workers</td><td>0.03130
-0.00146
0.00004618</td><td>0.03078
-0.00147
0.00004621</td><td rowspan="3">N/A</td><td>0.0391
-0.00146
0.00004618</td><td>0.1093
-0.00146
0.00004618</td><td>0.0382
-0.00144
0.00004621</td><td>0.1107047
-0.00143
0.00004621</td><td rowspan="3">N/A</td></tr>
<tr><td>Life-cycle permanent shock profile of male risk-averse workers</td><td>0.01843
-0.0008566
0.00002781</td><td>0.01864
-0.0008571
0.00002786</td><td>0.02623
-0.0008566
0.00002781</td><td>0.01843
-0.0008566
0.00002781</td><td>0.02567
-0.0008559
0.00002778</td><td>0.01853
-0.0008569
0.00002784</td></tr>
<tr><td>Life-cycle transitory shock profile of male risk-tolerant workers</td><td>0.05916
-0.01082
0.00102
-0.00003613
4.36e-7</td><td>0.05946
-0.01079
0.00103
-0.00003609
4.35e-7</td><td>0.08796
-0.01082
0.00102
-0.00003613
4.36e-7</td><td>0.34716
-0.01082
0.00102
-0.00003613
4.36e-7</td><td>0.08813
-0.01083
0.00100
-0.00003609
4.36e-7</td><td>0.34074
-0.01079
0.00100
-0.00003611
4.36e-7</td></tr>
</table>

Life-cycle transitory shock profile of male risk-averse workers	0.04188 -0.00766 0.0007199 -0.00002557 3.09e-7	0.04187 -0.00771 0.0007201 -0.00002553 3.09e-7		0.07068 -0.00766 0.0007199 -0.00002557 3.09e-7	0.04188 -0.00766 0.0007199 -0.00002557 3.09e-7	0.07112 -0.00769 0.0007201 -0.00002560 3.09e-7	0.04186 -0.00769 0.0007201 -0.00002555 3.09e-7	
Life-cycle permanent shock profile of female risk-tolerant workers	0.02570 -0.00101 0.00002654	0.02604 -0.00104 0.00002656		0.0335 -0.00101 0.00002654	0.1037 -0.00101 0.00002654	0.0341 -0.00103 0.00002652	0.0997 -0.00998 0.00002656	
Life-cycle permanent shock profile of female risk-averse workers	0.02292 -0.0008967 0.00002366	0.02311 -0.0008973 0.00002368		0.03072 -0.0008967 0.00002366	0.02292 -0.0008967 0.00002366	0.03008 -0.0008958 0.00002371	0.02297 -0.0008970 0.00002367	
Life-cycle transitory shock profile of female risk-tolerant workers	0.1000 -0.00355 0.00024958 -0.00001094 1.65e-7	0.0976 -0.00351 0.00024961 -0.00001090 1.65e-7		0.0900 -0.00355 0.00024958 -0.00001094 1.65e-7	0.0001	0.0913 -0.00351 0.00025010 -0.00001092 1.65e-7	0.0042	
Life-cycle transitory shock profile of female risk-averse workers	0.08758 -0.00311 0.00021857 -0.00000958 1.45e-7	0.08803 -0.00309 0.00021851 -0.00000954 1.45e-7		0.07758 -0.00311 0.00021857 -0.00000958 1.45e-7	0.08758 -0.00311 0.00021857 -0.00000958 1.45e-7	0.07774 -0.00310 0.00021860 -0.00000955 1.45e-7	0.08767 -0.00311 0.00021854 -0.00000954 1.45e-7	
Persistency of permanent wage shocks for risk-tolerant male, risk-averse male, risk-tolerant female, risk-averse female, respectively	0.935 0.966 0.943 0.948	0.937 0.969 0.945 0.950		0.935 0.966 0.943 0.948	0.935 0.966 0.943 0.948	0.936 0.968 0.943 0.950	0.933 0.966 0.939 0.948	

Sources: (a) Average household market hours: the authors' calculation using the PSID. Male average market hours are normalized to 1/3 (0.3333). Female market hours are calculated accordingly. (b) Ratio of female to male market hours: the authors' calculation using the PSID. (c) Male per capita employment: the authors' calculation using the CPS March. (d) Female per capita employment: the authors' calculation suing the CPS March. (e) Capital-to-output ratio: Bureau of Economic Analysis (f) Gender wage gap: the authors' calculation using the PSID. (g) Gini coefficient of income: Census Bureau. Life-cycle wage shock profiles, permanent and transitory, for each gender-preference group: the authors' calculation using the PSID and the NLSY. Numbers in each category of life-cycle shock profiles represent coefficients of a polynomial function with the first number being a constant and the last the leading coefficient. See the text for the derivation of these profiles.

Table 3. Summary of Internally Determined Parameters

Parameter		1970s		2000s		
		Heterogeneous	Homogeneous	Heterogeneous		Homogeneous
				A	B	
λ	Share of male labor in total labor input	0.619 (0.072)	0.615 (0.072)	0.582 (0.074)	0.585 (0.078)	0.580 (0.068)
χ_m	Disutility of male work	41.038 (4.003)	363.568 (20.341)	7.458 (0.645)	7.986 (0.974)	53.932 (4.053)
χ_f	Disutility of female work	28.421 (2.649)	271.157 (16.346)	4.990 (0.491)	5.413 (0.773)	36.753 (3.174)
β	Discount factor	0.957 (0.075)	0.936 (0.056)	0.953 (0.073)	0.956 (0.087)	0.942 (0.060)
$\underline{a}$	Borrowing limit	-0.182 (0.028)	-0.176 (0.026)	-0.240 (0.037)	-0.241 (0.044)	-0.238 (0.033)
b	Retirement benefits	0.306 (0.019)	0.295 (0.017)	0.404 (0.024)	0.405 (0.038)	0.399 (0.022)
$(\beta_0^{m,p,r} - \beta_4^{m,p,r})$	Life-cycle permanent shock profile of male in risky jobs	0.0337 (0.002112) -0.00147 (0.000164) 0.00004621 (1.8e-6)	N/A	0.0426 (0.00262) -0.00147 (0.000174) 0.0000459 (1.8e-6)	0.1137 (0.01246) -0.00145 (0.000295) 0.0000457 (2.1e-6)	N/A
$(\beta_0^{m,p,s} - \beta_4^{m,p,s})$	Life-cycle permanent shock profile of male in safe jobs	0.01686 (0.00128) -0.0008607 (0.000038) 0.00002703 (1.5e-6)	N/A	0.01743 (0.00156) -0.0008506 (0.000042) 0.000027 (1.6e-6)	0.09903 (0.01004) -0.0008574 (0.000055) 0.00002648 (1.7e-6)	N/A
$(\beta_0^{m,t,r} - \beta_4^{m,t,r})$	Life-cycle transitory shock profile of male in risky jobs	0.06731 (0.00424) -0.01090 (0.00088) 0.00100 (0.000081) -0.00003568 (1.2e-6) 4.36e-7 (2.2e-8)	N/A	0.08994 (0.00504) -0.01080 (0.00091) 0.00103 (0.000083) -0.00003631 (1.1e-6) 4.36e-7 (2.3e-8)	0.34927 (0.03311) -0.01081 (0.00124) 0.00103 (0.000101) -0.00003654 (1.6e-6) 4.36e-7 (2.8e-8)	N/A
$(\beta_0^{m,t,s} - \beta_4^{m,t,s})$	Life-cycle transitory shock profile of male in safe jobs	0.03803 (0.00224) -0.00758 (0.00051) 0.0007191 (0.000066) -0.00002561 (1.0e-6) 3.08e-7 (1.7e-8)	N/A	0.06493 (0.00426) -0.00786 (0.00052) 0.0007191 (0.000068) -0.00002539 (1.0e-6) 3.08e-7 (1.7e-8)	0.04039 (0.00317) -0.00778 (0.00069) 0.0007201 (0.000082) -0.00002534 (1.2e-6) 3.08e-7 (1.9e-8)	N/A

$(\beta_0^{f,p,r} - \beta_4^{f,p,r})$	Life-cycle permanent shock profile of female in risky jobs	0.02748 (0.00201) -0.000994 (0.000071) 0.00002561 (1.1e-6)	N/A	0.03538 (0.00272) -0.00100 (0.00076) 0.00002596 (1.1e-6)	0.1071 (0.00891) -0.000998 (0.00097) 0.00002621 (1.6e-6)	N/A
$(\beta_0^{f,p,s} - \beta_4^{f,p,s})$	Life-cycle permanent shock profile of female in safe jobs	0.02109 (0.00137) -0.0008894 (0.000042) 0.00002401 (1.1e-6)	N/A	0.02137 (0.00162) -0.0008906 (0.000046) 0.00002403 (1.2e-7)	0.02203 (0.00173) -0.0009002 (0.000052) 0.00002386 (1.3e-7)	N/A
$(\beta_0^{f,t,r} - \beta_3^{f,t,r})$	Life-cycle transitory shock profile of female in risky jobs	0.10531 (0.05767) -0.00368 (0.00027) 0.00025013 (0.00001137) -0.00001086 (8.2e-7) 1.65e-7 (8.6e-10)	N/A	0.09546 (0.05844) -0.00366 (0.00029) 0.00024813 (0.00001210) -0.00001083 (8.5e-7) 1.65e-7 (8.8e-10)	0.0073 (0.00051)	N/A
$(\beta_0^{f,t,s} - \beta_3^{f,t,s})$	Life-cycle transitory shock profile of female in safe jobs	0.08393 (0.00574) -0.00307 (0.000194) 0.0002183 (0.0000164) -0.00000961 (5.1e-7) 1.45e-7 (9.4e-9)	N/A	0.07409 (0.00567) -0.00305 (0.000197) 0.0002187 (0.0000169) -0.00000962 (6.1e-7) 1.45e-7 (9.6e-9)	0.08605 (0.00621) -0.00309 (0.000205) 0.0002183 (0.0000179) -0.0000096 (6.5e-7) 1.45e-7 (1.0e-8)	N/A
$\rho^{m,r}, \rho^{m,s}, \rho^{f,r}, \rho^{f,s}$	Persistency of permanent wage shocks for male in risky, male in safe, female in risky, female in safe jobs, respectively	0.931 (0.0734) 0.970 (0.0681) 0.940 (0.0859) 0.954 (0.0733)	N/A	0.930 (0.0737) 0.971 (0.0686) 0.939 (0.0861) 0.953 (0.0738)	0.918 (0.0789) 0.966 (0.0693) 0.920 (0.0911) 0.947 (0.0739)	N/A

Numbers in parentheses are estimated standard errors obtained by the Simulated Methods of Moments estimation. See notes to Table 2.

Table 4. Welfare Costs of Increased Wage Shocks: Case A

Type of Shocks	Homogeneous Risk Preferences ω' (%) (a)	Heterogeneous Risk Preferences ω (%) (b)	Overstatement of Welfare Cost/Gain (%) (a)/(b)
Δ All Types of Shocks	14.13	8.47	1.67
Δ Male permanent	7.88	4.47	1.76
Δ Male transitory	2.10	1.12	1.88
Δ Female permanent	3.89	2.33	1.67
Δ Female transitory	-0.51	-0.31	1.65

The welfare costs are generated by the increased gender-specific permanent and transitory wage shocks from the early 1970s to the 2000s, assuming that the model parameters and economic conditions remain unchanged at the 1970s levels. (See equation (19) for our working definition of the welfare cost.) Between the early 1970s and 2000s, variances of male permanent, male transitory, female permanent, and female transitory shocks have increased by 0.0078 (from 0.0163 to 0.0241), 0.0288 (from 0.0217 to 0.0505), 0.0078 (from 0.0175 to 0.0253), and -0.0100 (from 0.0639 to 0.0539), respectively. Case A refers to when the increased wage shocks are economy-wide in the sense that both risk-tolerant and risk-averse groups face the same amount of increase in wage shocks, permanent or transitory.

Table 5. Effectiveness of Family Labor Supply and Borrowing/Saving as Insurance Measures against Welfare Reduction: Case A

	Both Insurance Measures Are Adjusted		Family Labor Supply Fixed at the Early 1970s Level		Borrowing/Saving Fixed at the Early 1970s Level		Both Measures Are Fixed at the Early 1970s Level		Interactive Insurance Effects of Two Measures	
	Homo-geneous	Hetero-geneous	Homo-geneous	Hetero-geneous	Homo-geneous	Hetero-geneous	Homo-geneous	Hetero-geneous	Homo-geneous	Hetero-geneous
Δ All Types of Shocks	14.13 - [11.86]	8.47 - [6.51]	22.25 (8.13) [3.74]	12.87 (4.40) **[2.11]**	20.71 (6.58) [5.28]	12.08 (3.61) **[2.90]**	25.99 (11.86) -	14.98 (6.51) -	2.85	1.50
Δ Male Permanent	7.88 - [5.88]	4.47 - [3.75]	12.19 (4.31) [1.56]	7.19 (2.72) **[1.03]**	10.86 (2.98) [2.90]	6.32 (1.85) **[1.90]**	13.76 (5.88) -	8.22 (3.75) -	1.41	0.82
Δ Male Transitory	2.10 - [1.77]	1.12 - [1.05]	2.77 (0.67) [1.10]	1.51 (0.39) **[0.66]**	3.62 (1.52) [0.24]	2.02 (0.15) **[0.04]**	3.87 (1.77) -	2.17 (1.05) -	0.42	0.24
Δ Female Permanent	3.89 - [2.49]	2.33 - [1.37]	5.74 (1.85) [0.64]	3.33 (1.00) **[0.37]**	5.13 (1.24) [1.25]	3.00 (0.70) **[0.70]**	6.38 (2.49) -	3.70 (1.37) -	0.60	0.30
Δ Female Transitory	-0.51 - [0.37]	-0.31 - [0.20]	-0.37 (0.14) [0.23]	-0.23 (0.08) [0.12]	-0.18 (0.33) [0.04]	-0.14 (0.17) [0.03]	-0.14 (0.37) -	-0.11 (0.20) -	0.10	0.05

See Notes to Table 4. Numbers in parentheses represent additional welfare costs of not using an insurance measure (or measures), relative to the case of all insurance measures being fully adjusted. Those in brackets stand for additional welfare gains of using an insurance measure (measures), relative to the case of no adjustment in any insurance measure. Numbers in parentheses and brackets are in percentage points.

Table 6. Details on Effectiveness of Family Labor Supply Adjustment as an Insurance Mechanism in Heterogeneous Model: Case A

	Borrowing/Saving Adjusted					Borrowing/Saving Fixed				
	Both Insurance Measures Are Adjusted (a)	Self Labor Supply Adjustment Not Allowed (b)	Family Labor Supply Fixed (c)	Added Worker Effects =(c)-(b)	Effects of Self Labor Supply Adjustment =(b)-(a)	Added Worker Effect =(f)-(e)	Effects of Self Labor Supply Adjustment =(e)-(d)	Family Labor Supply Adjusted (d)	Only Spouse Labor Supply Adjusted (e)	Both Measures Are Fixed at the 1970s Level (f)
Δ Male Permanent	4.47	5.58	7.19	**1.61**	**1.11**	**1.19**	**0.70**	6.32	7.02	8.22
Δ Female Permanent	2.33	2.64	3.33	**0.70**	**0.31**	**0.54**	**0.16**	3.00	3.16	3.70

See notes to Table 4.

Table 7. More on 'Added-Worker' Effects

Case	Shock Type	Intensive/ Extensive Margins	Employment/ Hours	Borrowing/Saving Allowed				Borrowing/Saving Fixed			
				Before (1970s)	After (2000s)	%Δ total hours	Elasticity	Before (1970s)	After (2000s)	%Δ total hours	Elasticity
Case A	Male Perm	Intensive	Employment	0.42	0.42	2.251	0.047	0.421	0.421	3.215	0.067
			Hours	0.311	0.318			0.311	0.321		
		Extensive	Employment	0	0.034	7.054	0.147	0	0.048	10.082	0.211
			Hours	0	0.271			0	0.275		
		Total	Employment	0.42	0.454	9.305	0.194	0.421	0.469	13.297	0.278
			Hours	0.311	0.314			0.311	0.316		
	Female Perm	Intensive	Employment	0.900	0.900	1.923	0.043	0.900	0.900	2.747	0.062
			Hours	0.364	0.371			0.364	0.374		
		Extensive	Employment	0	0.014	1.316	0.030	0	0.021	2.077	0.047
			Hours	0	0.308			0	0.324		
		Total	Employment	0.9	0.914	3.239	0.073	0.900	0.921	4.824	0.108
			Hours	0.364	0.370			0.364	0.373		
Case B	Male Perm	Intensive	Employment	0.423	0.423	0.643	0.013	0.423	0.423	0.965	0.020
			Hours	0.311	0.313			0.311	0.314		
		Extensive	Employment	0	0.018	3.763	0.079	0	0.026	5.514	0.115
			Hours	0	0.275			0	0.279		
		Total	Employment	0.423	0.441	4.406	0.092	0.423	0.449	6.479	0.135
			Hours	0.311	0.311			0.311	0.312		
	Female Perm	Intensive	Employment	0.9	0.9	0.824	0.018	0.900	0.900	1.099	0.025
			Hours	0.364	0.367			0.364	0.368		
		Extensive	Employment	0	0.008	0.786	0.018	0	0.012	1.187	0.027
			Hours	0	0.008			0	0.324		
		Total	Employment	0.9	0.908	1.611	0.036	0.900	0.912	2.286	0.052
			Hours	0.364	0.367			0.364	0.367		

The average labor hour among the entire male population in the early 1970s is normalized as 0.333. Male permanent and female permanent wage shocks increased by 48 and 45 percent, respectively, from the early 1970s to the 2000s.

Table 8. Welfare Costs of Increased Wage Shocks and Effectiveness of Insurance measures in Heterogeneous Economy: Case B

	Both Insurance Measures Are Adjusted	Family Labor Supply Fixed at the Early 1970s Level	Borrowing/Saving Fixed at the Early 1970s Level	Both Measures Are Fixed at the Early 1970s Level	Interactive Insurance Effects of Two Measures
Δ All Types of Shocks	4.91 - [3.83]	7.87 (2.96) [0.87]	6.58 (1.67) [2.16]	8.74 (3.83) -	0.80
Δ Male Permanent	2.89 - [2.18]	4.76 (1.87) [0.31]	3.74 (0.86) [1.32]	5.07 (2.18) -	0.54
Δ Male Transitory	0.71 - [0.50]	0.97 (0.25) [0.25]	1.07 (0.36) [0.14]	1.22 (0.50) -	0.11
Δ Female Permanent	1.38 - [0.89]	2.13 (0.76) [0.13]	1.71 (0.33) [0.56]	2.27 (0.89) -	0.20
Δ Female Transitory	-0.19 - [0.09]	-0.15 (0.04) [0.05]	-0.13 (0.06) [0.02]	-0.11 (0.09) -	0.02

See notes to Table 4. Case B refers to when only the risk-tolerant group experiences wage shock increases, and the wages shocks for the risk-averse groups remain at the 1970s level. Section IV.2.A explains how to make the two cases comparable. Numbers in parentheses represent additional welfare costs of not using an insurance measure (or measures), relative to the case of all insurance measures being fully adjusted. Those in brackets represent additional welfare gains of using an insurance measure (measures), relative to the case of no adjustment in any insurance measure. All are in percentage points. All the analyses are conducted in the economy with heterogeneous risk preferences.

Table 9. Details on Effectiveness of Family Labor Supply Adjustment as an Insurance Measure in Heterogeneous Model: Case B

	Borrowing/Saving Adjusted					Borrowing/Saving Fixed				
	Both Insurance Measures Are Adjusted (a)	Self Labor Supply Adjustment Not Allowed (b)	Family Labor Supply Fixed (c)	Added Worker Effects =(c)-(b)	Effects of Self Labor Supply Adjustment =(b)-(a)	Added Worker Effect =(f)-(e)	Effects of Self Labor Supply Adjustment =(e)-(d)	Family Labor Supply Adjusted (d)	Only Spouse Labor Supply Adjusted (e)	Both Measures Are Fixed at the 1970s Level (f)
Δ Male Permanent	2.89	3.49	4.76	**1.27**	**0.60**	**0.99**	**0.34**	3.74	4.08	5.07
Δ Female Permanent	1.38	1.54	2.13	**0.60**	**0.16**	**0.49**	**0.08**	1.71	1.78	2.27

See notes to Tables 4 and 8.

Table 10. Perfect Foresight vs. Myopic Beliefs about Wage Shocks: Heterogeneous Risk Preferences

	Perfect Foresight		Myopic Beliefs	
	Case A (%)	Case B (%)	Case A (%)	Case B (%)
Δ All Types of Shocks	8.47	4.91	12.44	6.34
Δ Male permanent	4.47	2.89	6.61	3.78
Δ Male transitory	1.12	0.71	1.66	0.93
Δ Female permanent	2.33	1.38	3.42	1.78
Δ Female transitory	-0.31	-0.19	-0.39	-0.24

See notes to Tables 4 and 8. Estimates in the first two columns are obtained by assuming that the 1970s households foresee perfectly how the life-cycle wage shock profiles will change in the 2000s. Those in the last two columns are derived under the assumption that the 1970s households mistakenly believe that the magnitudes and life-cycle patterns of wage shocks will remain unchanged in the future, but face the realized wage shocks that are generated under the 2000s wage structure.

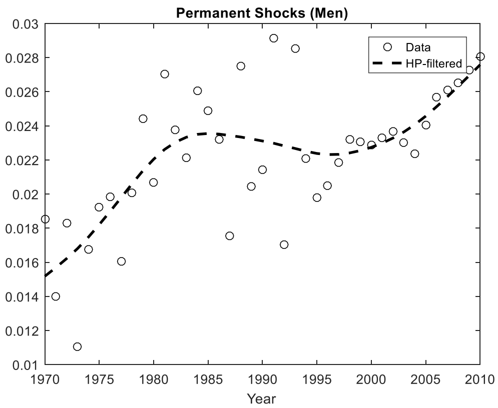
Table 11. Considering General Equilibrium Effects and Changing Economic Conditions

	Case A	Case B
Prices fixed at the 1970s level	8.47 %	4.91 %
General equilibrium effects allowed	9.04 % (Δ 0.57%P)	5.19 % (Δ 0.28%P)
All the economic conditions are changed to the 2000s levels	-0.36 % (∇ 8.83%P)	-3.99 % (∇ 8.90%P)
Increase in TFP	2.89 % (∇ 5.58%P)	-0.71 % (∇ 5.62%P)
Gender-biased demand shifts	6.52 % (∇ 1.95%P)	2.93 % (∇ 1.98%P)

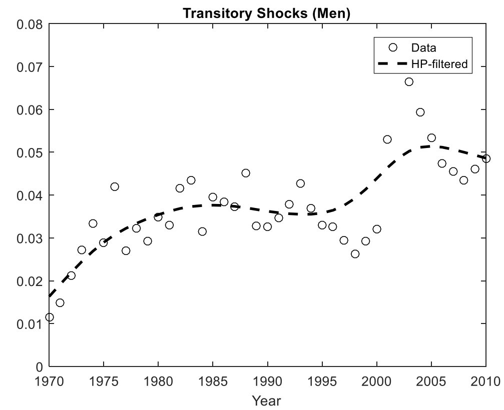
See notes to Tables 4 and 8.

Figure 1. Variances of Wage Shocks

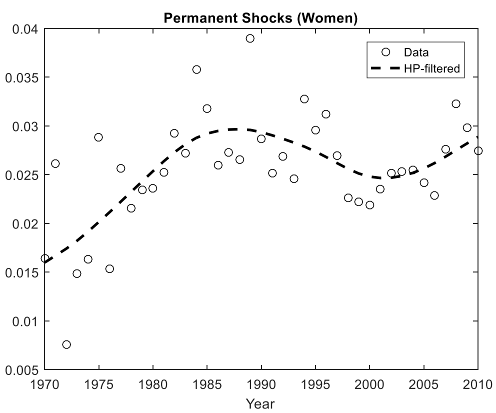
(a) Male Permanent Wage Shocks



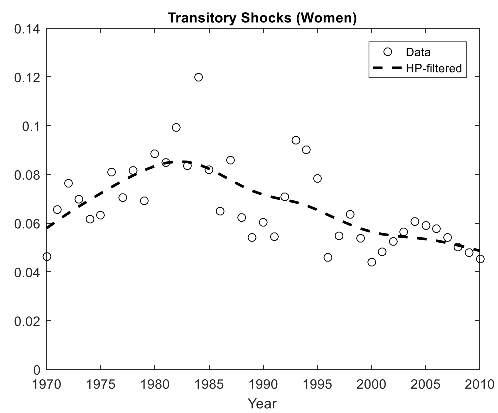
(b) Male Transitory Wage Shocks



(a) Female Permanent Wage Shocks

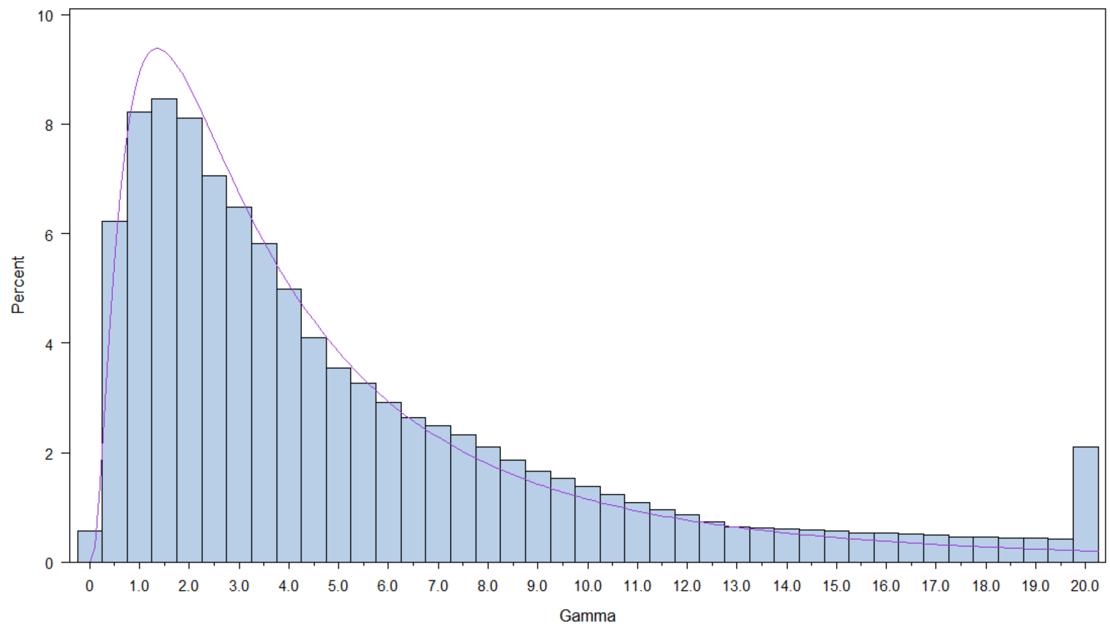


(b) Female Transitory Wage Shocks



Source: The Panel Study of Income Dynamics, 1970-2010. See the text for estimation methodology, and Appendix 1 for sample restrictions and variable definitions.

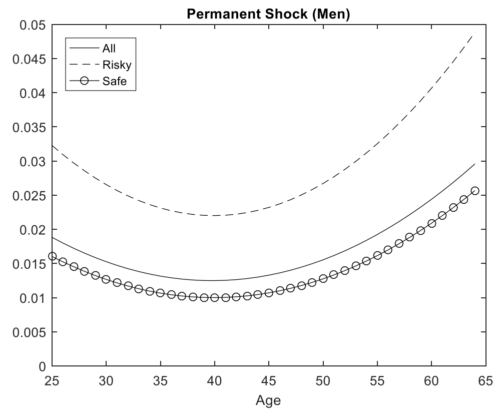
Figure 2. Distribution of Individual Risk Aversions



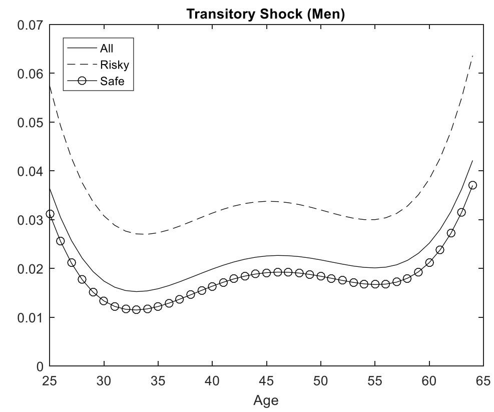
Source: The NLSY79, 1979-2010. Both genders are included, and age range is 25-64. See the text for details of the construction process.

Figure 3. Comparison of Wage Shock Profiles between Homogeneous and Heterogeneous Economies in the 1970s Economy

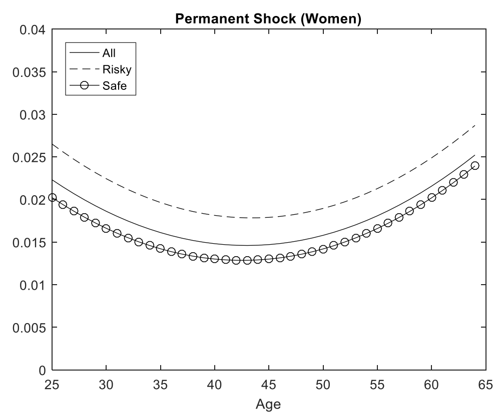
(a) Variance of Male Permanent Shock



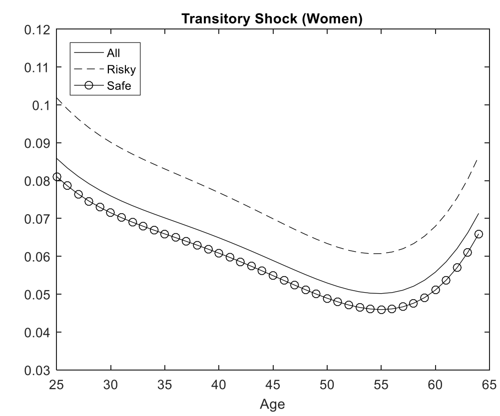
(b) Variance of Male Transitory Shock



(c) Variance of Female Permanent Shock

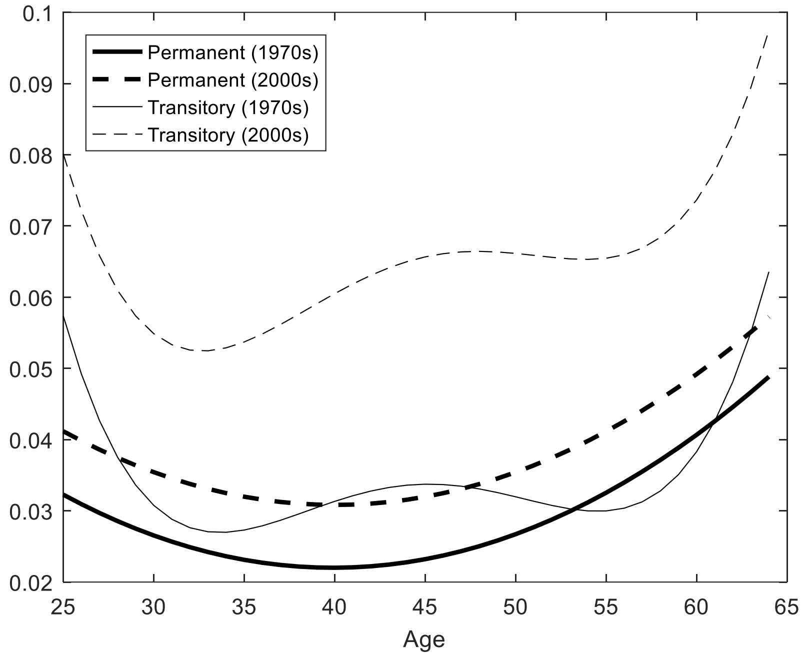


(d) Variance of Female Transitory Shock

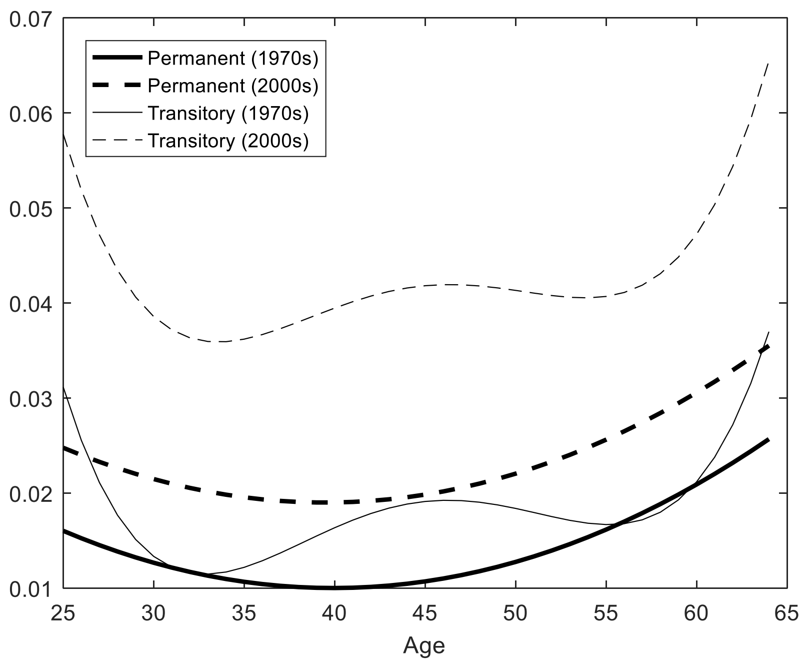


Source: authors' estimation using both the PSID (1970-2013) and NLSY79 (1979-2010). See the text and Appendix 2 for the estimation procedure. The sample includes married females who are 25-64 years old. The lines connecting circular data points and the dashed lines represent life-cycle profiles of wage shocks someone would face in safe and risky jobs, respectively. The solid lines represent the life-cycle shock profiles in the homogeneous economy.

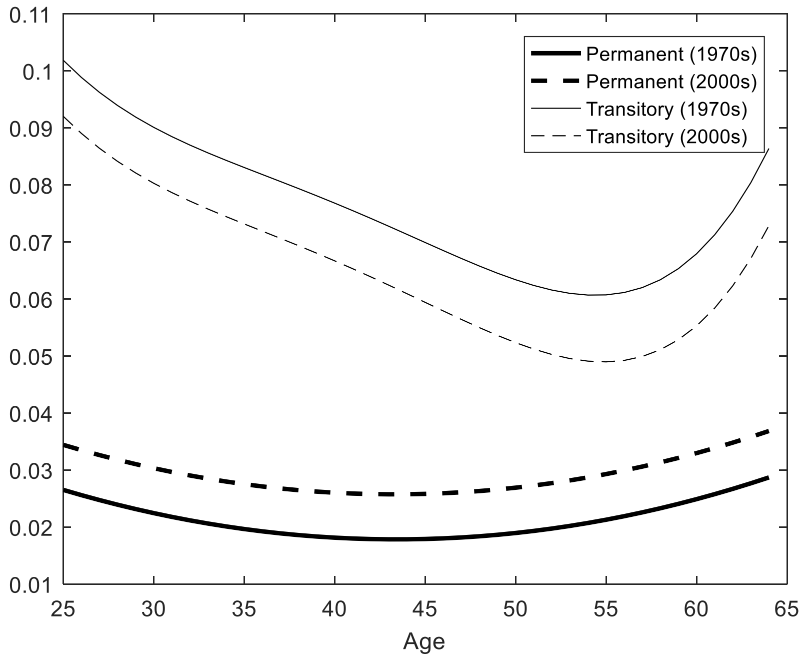
Figure 4. Changes in Gender-Job-Specific Wage Profiles from the 1970s to the 2000s



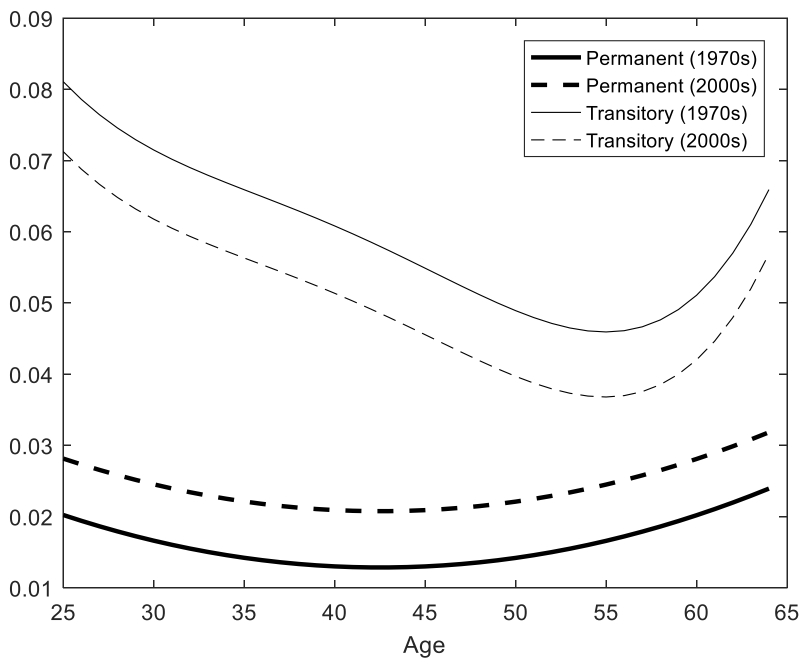
(a) Male risky job



(b) Male safe job



(c) Female risky job



(d) Female safe job

Appendix 1. Data

We use multiple sources of data, including the Panel Study of Income Dynamics (PSID), the National Longitudinal Study of Youth 1979 (NLSY79), and the Current Population Survey (CPS). The PSID is used to estimate trends in cross-sectional variances of permanent and transitory wage shocks from 1970 to 2010 and to derive life-cycle profiles of both permanent and transitory wage shocks for each gender. The NLSY79 is used to derive the empirical distribution of risk aversions and to construct life-cycle wage shock profiles for each of the risk-tolerant and risk-averse groups. The CPS is used to obtain various empirical moments, such as the average working hours by gender, per capita employment by gender, and the Gini coefficient, that are used in estimating the current models.

We use the data from the nationally representative component of the PSID sample, the Survey of Research Center. Following existing studies (e.g., Heathcote et al., 2010), we define the hourly wage rate as the ratio of total annual labor income to annual hours. The total labor income is a comprehensive earnings measure, which includes, in addition to wage and salary income, bonuses, overtime, tips, commissions, and the labor parts of farm and business income. As noted by Shin and Solon (2011), the PSID's treatment of business and farm income in total labor income has changed over the years, resulting in inconsistency in the total labor income variable over time. We therefore exclude business and farm income from the total labor income. We also exclude imputations for missing values. Wage rates are deflated by CPI-U-RS in 2010 dollars.

For the NLSY79, we use total annual labor income divided by annual hours as the average hourly earnings variable. Total labor income includes wages, salary, overtime pay, commissions, and tips from all jobs. We restrict our sample to those who are married, between the ages of 25 and 64, and who work at least 100 hours per year. The same sample restrictions are applied to the NLSY79 with the exception of the age restriction. Since we use the NLSY79 until 2012, it contains individuals who are at most 54 years old. To obtain results comparable to those from the PSID, we use only the national random sample, but exclude supplement and military samples.

Appendix 2. Estimation of Wage Processes

Following Heathcote et al. (2010), among others, we model wage residuals as the sum of two orthogonal components, persistent and transitory components. We estimate trends in cross-sectional variances of wage shocks using the PSID for the period of 1970-2010 in income years. Since the PSID switched the survey from annual to biennial beginning in 1997 (1996 income year), wage shock variances cannot be estimated for some years (1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011 in survey years). To resolve this issue, following Heathcote et al. (2010), we assume that the cross-sectional variance in a missing year is a weighted average of the two variances in neighboring years.

We first define the parameter vector, $\boldsymbol{\theta} = \{\{\rho^{g}, \left(\sigma_{\epsilon_t}^{g}\right)^2, \left(\sigma_{\eta_t}^{g}\right)^2\}_{t=1970}^{2010}\}_{g\in\{m,f\}}$. For each year t and each gender g, we group individuals in the sample into 10-year adjacent age cells indexed by j. For example, the first age cell includes individuals between 25-34, the second 35-44, …, all the way up to the last age cell including individuals between 55-64. Then, we compute the covariance in the age-year cells using wage residuals from equation (18). The moment conditions used in the estimation have the following form:

$$g(\boldsymbol{\theta}) = M_d - M_m(\boldsymbol{\theta}),$$

where M_d is the empirical covariance between wages of individuals of age j at time t and the wages of the same individuals n years later, defined as $M_d = \frac{1}{I_{j,t,n}} \sum_{i=1}^{I_{j,t,n}} z_{i,j,t} \cdot z_{i,j,t+n}$, where I is the number of individuals observed between time t and $t+n$ at age j; $M_m(\boldsymbol{\theta})$ is the theoretical covariance. Then, the estimator minimizes the following function:

$$\widehat{\boldsymbol{\theta}}_{GMM} = \arg\min_{\boldsymbol{\theta}} g(\boldsymbol{\theta})' W g(\boldsymbol{\theta}),$$

where W is a weighting matrix. Following Altonji and Segal (1996), we use an identity matrix for W.

The life-cycle profiles of wage shocks are estimated in a similar fashion except that we regroup the entire sample into 1-year age cells.

Appendix 3. Simulated Method of Moments

The model estimation processes for the 1970s and the 2000s are the same. Thus, we only describe the processes for the 1970s economy in this appendix.

Let M_d represent a vector of empirical moments that are computed from various data sources in the US, as described in Table 2. There are 9 and 45 empirical moments for the homogeneous and heterogeneous economy, respectively. Let $\boldsymbol{\beta}' \equiv \{\lambda, \chi^m, \chi^f, \beta, \underline{a}, b, \beta_0^{g,h,s} - \beta_4^{g,h,s}\}$ represent the 42 structural parameters to be estimated internally. For the homogeneous economy, $\boldsymbol{\beta}' \equiv \{\lambda, \chi^m, \chi^f, \beta, \underline{a}, b\}$. Given the externally determined parameter values, we obtain 100,000 households. We use the model to simulate their life-cycle labor hours, savings, and job choices, and generate the moments analogous to the empirical moments, denoted by $M_m(\boldsymbol{\beta})$ (again, 9 and 45 moments for the homogeneous and heterogeneous economies, respectively). Obviously, each of these model-generated moments is a function of a set of deeper structural parameters, $\boldsymbol{\beta}$. We define the column vector of deviations of the empirical moments from corresponding model-generated moments by $g(\boldsymbol{\beta}) = M_d - M_m(\boldsymbol{\beta})$. The simulated Method of Moments (SMM) estimator chooses the value of $\boldsymbol{\beta}$ that minimizes the weighted sum of the squared deviations between the empirical and model-generated moments:

$$\widehat{\boldsymbol{\beta}}_{SMM} = \arg\min_{\boldsymbol{\beta}} g(\boldsymbol{\beta})' W g(\boldsymbol{\beta}),$$

where W is some optimal weighting matrix. The variance-covariance matrix of $\widehat{\boldsymbol{\beta}}_{SMM}$ is estimated by

$$\hat{\Sigma}_{\hat{\beta}} = \left(\widehat{G'}W\hat{G}\right)^{-1}\widehat{G'}W\Omega W\hat{G}\left(\widehat{G'}W\hat{G}\right)^{-1},$$

where $\hat{G} = \frac{\partial}{\partial \beta} g(\boldsymbol{\beta})|_{\boldsymbol{\beta}=\hat{\boldsymbol{\beta}}}$, and Ω is the variance-covariance matrix of the empirical moments. We estimate the model with an optimal weighting matrix $\mathrm{W} = \Omega^{-1}$.

Appendix 4. Solution Algorithm (Heterogeneous Economy)

Given a set of model parameters, $\boldsymbol{\beta} \equiv \{\lambda, \chi^m, \chi^f, \beta, \underline{a}, b, \beta_0^{g,h,s} - \beta_4^{g,h,s}\}$ for $g \in \{m, f\}$, $h \in \{p, t\}$, $s \in \{r, s\}$, we

1) Generate a discrete grid over the state space along with the risk aversion space and couple's choices of job types (9 cases), where we discretize a support of γ into 15, a into 50, j into 60, η^m into 10, η^f into 10, ϵ^m into 2, and ϵ^f into 2 points.
2) Guess the shares of males and females in the risky job and the safe job ($s_0^{r,m}, s_0^{r,f}, s_0^{s,m}, s_0^{s,f}$), interest rate ($r_0$), and gender-specific labor (H_0^m, H_0^f); and we compute the other two prices using equation (11).
3) Solve the job-specific value functions and saving functions.
4) Compute the stationary distributions (μ) by simulating a large sample of 100,000 households.
5) Compute aggregates for capital and (gender-specific) labor as in equations (12)-(14).
6) Check asset and labor market clearing conditions and get ($s_1^{r,m}, s_1^{r,f}, s_1^{s,m}, s_1^{s,f}$), ($H_1^m, H_1^f$), and r_1.
7) Update ($s_0^{r,m}, s_0^{r,f}, s_0^{s,m}, s_0^{s,f}, H_0^m, H_0^f$) and r_0 until markets clear and $s_1^{r,m} \approx s_0^{r,m}$, $s_1^{r,f} \approx s_0^{r,f}$, $s_1^{s,m} \approx s_0^{s,m}$, $s_1^{s,f} \approx s_0^{s,f}$, $H_1^m \approx H_0^m$, $H_1^m \approx H_0^m$, and $r_1 \approx r_0$.
8) Get the consumption functions.
9) Check the final goods market clearing condition and the government budget constraint.

For the homogeneous economy, the algorithm is much simpler in that we only solve for one type of value function and decision rule with a smaller state space.

Appendix 5. Derivation of the Observed Life-Cycle Wage Shock Profiles by Gender and by Preference Group for the early 1970s and 2000s Economies.

For brevity, we take the case of men's permanent wage shocks for both risk-tolerant and risk-averse groups. Parallel explanations are applied for men's transitory, women's permanent, and women's transitory shocks.

Observed life-cycle wage shock profiles for the heterogeneous economy in the early 1970s

1) We use the PSID 1971-2011 and the GMM method described in Appendix 2 to construct the life-cycle profile of variances of permanent wage shocks.
2) We use population shares by age and gender (from www.census.gov) and calculate the weighted average of variances, which is denoted by σ^2_{all} . This life-cycle average corresponds to the average variance of male permanent shocks in panel (a) of Figure 1 over 1970-2010. To derive the men's life-cycle permanent shock profile for the early 1970s economy, we need to adjust differences between the early 1970s and the middle point of the PSID sample period in the average permanent shock. Again, use panel (a) of Figure 1 to compute the average variance of male permanent shocks in the early 1970s (σ^2_{70s}), and subtract it from σ^2_{all}, which is denoted by σ^2_{dif}.
3) We subtract σ^2_{dif} from the life-cycle shock profile obtained in step 1) at each stage to derive the life-cycle male permanent shock profile for the 1970s economy. The underlying assumption at this step is that changes in cross-sectional variance equally affect all stages of the life-cycle. Using the population shares of the early 1970s, however, we confirm that the weighted average of the constructed life-cycle shocks for the 1970s economy is remarkably similar to σ^2_{70s}.
4) Now we use the NLSY79, 1979-2010, and the same GMM method to construct the life-cycle profile of variances of permanent wage shocks and compare it to the one obtained from the PSID. Since the NLSY79 allows the life-cycle stages of up to 54, we run a regression of estimated variances on age, age squared, and age cubed, and construct the

variances of permanent shocks for the entire life-cycle. The results show that the life-cycle patterns and shapes are almost identical between the two data sets.

5) We divide the same NLSY79 sample between the risk-tolerant and risk-averse groups using the 10% rule described in the text, construct the life-cycle permanent shock profiles for each group, and then calculate the difference between the two groups in variance of the permanent wage shock at each stage of the life-cycle. These differences are denoted by $d_{25}, d_{26}, \dots, d_{64}$.
6) At each stage of the life-cycle, we calculate variances of the two groups by solving the following equation. At age 25, for example, we solve the following equation for $\sigma^2_{averse,25}$: $\sigma^2_{averse,25} \times .9 + (\sigma^2_{averse,25} + d_{25}) \times .1 = \sigma^2_{25}$, where σ^2_{25} represents variance of the male permanent shock at age 25 obtained from the PSID. $\sigma^2_{averse,25}$ and $(\sigma^2_{averse,25} + d_{25})$ represent, respectively, the variance of permanent wage shocks experienced by the risk-averse and the risk-tolerant groups at age 25.
7) Life-cycle profiles, permanent and transitory, for each gender and preference group are obtained in a similar fashion.
8) These empirical moments, together with the 9 additional moments previously mentioned, are used to identify the gender-job-specific wage shock profiles, permanent and transitory, for the 1970s economy by the Simulated Method of Moments.

<u>Observed life-cycle wage shock profiles for the heterogeneous economy in the 2000s</u>

Case A) We use estimates in panel (a) of Figure 1 to calculate the difference between 1970-1974 and 2002-2006 in the average male permanent wage shock. Then we use the difference to shift the life-cycle permanent wage shock profiles of both male risk-tolerant and risk-averse groups of the 1970s (obtained in step 6) and derive corresponding profiles of the 2000s. Step 8) applies.

Case B) At each stage of the life-cycle, we shift the life-cycle permanent shock profile of the male risk-tolerant group of the 1970s by ten times of the amount of the increased male permanent shock between 1970-1974 and 2002-2006 in Figure 1. We use the same male permanent shock profile for the risk-averse (obtained in step 6) for the 2000s economy. Apply the same method for male transitory, female permanent, and female transitory shocks. Step 8) applies.

Appendix 6: U.S. Pension system

Following Heathcote et al. (2010), we employ the U.S. social security benefit system in the model, which is referred to as the “primary insurance amount” (PIA). The PIA is the benefit a person would receive if he/she elects to begin receiving retirement benefits at his/her normal retirement age. At this age, the benefit is neither reduced for early retirement nor increased for delayed retirement. The PIA will be the sum of (a) 90% of the first 0.221 of his/her average indexed annual earnings, (b) 32% of his/her average indexed annual earnings over 0.221 and through 1.331, and (c) 15% of his/her average indexed annual earnings over 1.331.

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