Income Variance - Dynamics and their Heterogeneity

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I investigate how life-cycle events can interact the decomposition of Income volatility into permanent and transitory shocks, and what implications it has can be represented as a shock or if it suggests a different evolution in the underlying income dynamics. I investigate multiple ways of modelling the underlying income process, for several definitions of income and family units, and I find that the effects of divorce on individuals' income processes is large, particularly for definitions of income that include transfers or capital gains. The impact is for all definitions of family units, but is highest for dynamics of pooled resources, and then for women.

Introduction

The aim of this paper is to explore how the dynamics of income over individuals lives interact with their lifetime events, namely that of divorce, and observe if there is meaningful heterogeneity in the lifetime earnings dynamics induced by these events. I find that life cycle events are important in considering the stochastic process of earnings, and are an important component for the estimated volatility in individuals income dynamics.

I use high quality administrative data from Denmark for a long panel of individuals' resources, household dynamics and demographic characteristics. Access to high quality data such as this can allow for looking more extensively at panel dynamics in individuals' life-cycle resources across their lifecycle than has been possible in the past due to more detailed information about individuals' components of income, family background, and longer panels, as noted by Daly, Hryshko and Manovskii (2018*a*) and Blundell, Graber and Mogstad (2015). The large sample size allows me to look at individuals that underwent life-cycle events, particularly divorce, at a specific age for a specific cohort of individuals and still be able to estimate the entire model describing their earnings dynamics so I can consider life-cycle consequences of this event generally.

This paper contributes primarily to two strands of literature. The first is on the effects of life-cycle events on individuals' finances. Several papers have discussed the important role of life-cycle events,

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[†] I am deeply grateful to my thesis advisor, Steven Durlauf, for his tireless guidance and repeated help in exposing me to deep ideas as well urging me to think independently about them. I am similarly indebted to my research advisor, James Heckman, with whom I have had many fruitful conversations about these and a lifetime of other research ideas.

particularly divorce, on individuals' available resources, crucially those of women[1]. However, fewer papers have discussed the effects of divorce with regards to observed volatility in individuals' and family's resources and whether it affects the dynamics of resources available to the individuals. This paper shows that there are, as expected, meaningful effects of life-cycle events, such as divorce, on the volatility of individuals' income, which has implications for thinking about the evolution of inequality over individuals' lifecycles. For instance, Aassve A. (2004) document that in a number of Western countries, the probability of women following into poverty increases sharply around the event of a divorce, much more steeply than for men; however, the average net income increases by 32 percent due to the role of transfers by welfare and due to child support. This suggests that the second moments are a crucial component for consideration.

The second is the literature on looking at individuals' earnings dynamics. There is a longstanding literature looking at individuals' income dynamics, both for the purpose of modelling individuals income processes as in many structural models, as well as the economic content the parameters of such an estimation may have in and of themselves. The literature about earnings dynamics has often abstracted away from the actual events underlying the shocks that are observed, and especially so for life-cycle events. This paper takes a step towards understanding the effects of these events on individuals' dynamics, to see how important they may be for the purposes of modelling individuals' earnings processes correctly, and noting how the disruption fits within the existing models of income dynamics.

An often ignored question at the heart of this literature is the question of which definition of income, and what level of the household unit is most relevant in considering income dynamics. Much of the literature has looked at the wage incomes of always-married men. The entire profile of earnings dynamics, includes a number of different subcomponents that make up individuals' total earnings, including the role of taxes, transfers, and capital income, all of which have different implications for individuals' welfare. Each of these would have different dynamics, and they have different capacities for individuals to be able to insure against them.

[1]See, for instance, Robins (1986), Heath and Kiker (1992), Morrison and Ritualo (2000)

Literature Overview

The stochastic process for earnings is an important element for evaluating individuals' welfare, and seeing what level of volatility and uncertainty individuals face over time. The motivation for considering earnings dynamics comes from the seminal insights of Daly, Hryshko and Manovskii (2018*b*) and Friedman and Kuznet (1954) in the Permanent Income Hypothesis, as well as the work by Modigliani and Brumberg (1954) and Ando and Modigliani (1963) on the Life-Cycle Hypothesis. These papers recognized the importance of thinking more deeply about the volatility and dynamics in individuals' earnings. Absent any changes in individuals' information about their earnings capacity, individuals should strive to borrow from future periods to smooth their consumption over time.

The literature for studying earnings through modelling the permanent and transitory portions according to some parametric time series process (usually a combination of autoregressive and moving average components) has a long tradition in economics, with some of the earliest work being done by Lillard and Willis (1978) and Hause (1980) in formally writing down a model where the variances could be decomposed using techniques from time series analysis. One seminal work was by Macurdy (1982) who tests across several specifications and found the moving average specification for the transitory component to be the best fit for the data. Macurdy (1982) also writes a general model explaining the motivations behind the variance decomposition of individuals' income streams as arising out of time-series literature, such as by Granger and Newbold (1967), Granger and Newbold (1977), to estimate the variances for individuals' permanent and transitory components, as well as factor loadings for ages.

Several surveys, such as Meghir and Pistaferri (2011), Moffitt and Zhang (2018), and Browning, Hansen and Heckman (1999) have covered the findings of the seminal works in the literature. Fewer papers have modelled women's income processes the earnings dynamics literature, perhaps due to the necessity of modeling labor market participation for women. Notable work in this was done by Hyslop (2001), who builds a model of family labor supply and looks at the extent of permanence in income differences, intra-family correlations, and family labor supply behavior, investigating the role of permanent and transitory factors.

Income Process

We term $Y_{iat}^{k,f}$ for, k, a particular type of income for a particular family unit, f. For the sake of exposition, we remove the k, f. We view the individual's observed income as the sum of observable information, and the residual net of this expected income, y_{iat}, which is modeled as the sum of a random walk with drift, μ_{iat}, and a covariance stationary (cyclical) component, ν_{iat}. As described above, this allows us to think of individuals income as the sum of permanent random-walk component, the shocks to which persist for the entire working lifetime of an individual, and a mean-reverting stationary component, the shocks to which die out quickly. This is represented by the following:

$$\begin{aligned} y_{iat} &= \alpha_i + \mu_{iat} + \nu_{iat} \\ \mu_{iat} &= \mu_{ia-1t-1} + \omega_{iat} \\ \nu_{iat} &= \theta_a^q(L)\epsilon_{iat} \end{aligned} \tag{1}$$

Note, here, the permanent shocks, ω_{iat}, are defined such that $\partial\mu_{iat}/\partial\omega_{iat} = 1$. The $\theta_a^q(L)$ is a q^{th} degree polynomial in lag length, wherein the coefficients on the lags may depend on age a.

Process 1

In my primary specification, I investigate the prototypical formulation of this process where the transitory process evolves as MA(1), as in Macurdy (1982) [2]. Therein, we have $\nu_{iat} = \epsilon_{iat} + \theta\epsilon_{i,a-1,t-1}$.

This can be represented through a general error components framework. As discussed in Watson (1986), we can think of two different error processes (μ and ν) as unobserved components with the given structure. Clearly, there must be additional restrictions imposed on the ω_{iat} and the ϵ_{iat} to allow for identification, as both μ and ν are unobserved[3].

We have θ^j denote a jth order polynomial for the lag operator, L. Then, we can write the difference

[2] Here, I ignore the role of measurement error. Due to the high quality nature of the administrative data used, that may be reasonable - see Hryshko (2012)

[3] Note that in a seminal paper, Beveridge and Nelson decompose a time series trend into persistent and transitory components, but in their model, both the permanent and transitory components are linear combinations of the observed series, and are thus not wholly within the unobserved-components framework

as:

$$y_{i,a,t} - y_{i,a-1,t-1} = \delta + \theta^j(L)u_{iat}$$
$$\theta^j(L)u_{iat} = \omega_{iat} + (1-L)\theta^q(L)\epsilon_{iat}$$

As Watson (1986)[4] discusses, a sufficient assumption to identify all the parameters in the model is that ω_{iat} and ϵ_{iat} are uncorrelated, which puts a restriction on the spectrum for $y_{i,a,t} - y_{i,a-1,t-1}$, namely that the spectrum has a minimum at 0. Therein, we can solve for the coefficients in $\theta^q(L)$ by factoring according to (2);

$$\theta^j(z)\theta^j(z^{-1})\sigma_u^2 - \sigma_\omega^2 = (1-z)(1-z^{-1})\theta^q(z)\theta^q(z^{-1})\sigma_\epsilon^2 \tag{2}$$

We can explicitly write down the implied autocorrelations for this MA(1) representation.

$$Var(y_{iat}) = Var(\mu_{iat}) + Var(\nu_{iat}) = \sum_{a=1}^{t-1} Var(\omega_{i,a-k,t-k}^2) + Var(\epsilon_{iat}) + \theta^2(\omega_{ia-1t-1})$$
$$Cov(y_{iat}, y_{ia-1t-1}) = Var(\mu_{ia-1t-1}) + \theta Var(\nu_{iat})$$

Using these, we can estimate using the minimum distance estimator for the vector of moments ϑ.

$$\hat{\vartheta}_{MD} = \text{argmin}_{\vartheta} Q_{MQ1}(\vartheta, W_N(\vartheta))$$
$$Q_{MQ1}(\vartheta, W_N(\vartheta)) = [\overline{s}_N - \sigma_{zz}(\vartheta)]'\Omega_N^{-1}(\vartheta)[\overline{s}_N - \sigma_{zz}(\vartheta)]$$

Alternative Specification

I also try an additional richer specification, first used by Moffitt and Zhang (2018) [5] which does not restrict the MA process on the transitory components to be constant for all ages, and instead allows

[4]This discussion is presented with greater detail and more detailed exposition in Watson (1986), and Maravall (1996)
[5]This was first suggested briefly in in Moffitt and Gottschalk (2012)

for ν_{ia} to be a semi-parametric function of age.

(3)
$$y_{iat} = \alpha_t \mu_{ia} + \beta_t \nu_{ia}$$
$$\mu_{ia} = \mu_{ia-1} + \omega_{ia}$$
$$\nu_{ia} = \epsilon_{ia} + \sum_{s=1}^{a-1} \psi_{a,a-s} \epsilon_{is}$$

We should suspect from the previous discussion of the unobserved components model, that the terms should be identified as the degree of θ^q was arbitrary, and the restriction of ϵ_{it} and ω_{it} being uncorrelated still holds in this specification. However, in this model, we are also identifying the functions in $\psi_{a,a-r}$ so we need impose some parametric structure in another way on the ψ function to be able to identify all the moments.

$$\text{var}(\omega_{ik}) = e^{\sum_{j=t_0}^{T} \delta_j (r-t_0)^j}$$
$$\text{var}(\epsilon_{ik}) = e^{\sum \gamma_{j=t_0}^{T} (r-t_0)^j}$$
$$\psi_{1+T,1+T-k} = (1 - \pi(1 + T - t_0))(\sum_{j=t_0}^{T} w_j e^{\lambda_j k}) + \sum_{j=t_0}^{T} \eta_j D(k = j)$$

The parameters here are able to expand in a way that the parameters would go to zero as the lag length goes to infinity[6]. As above, the parameters are fit to the variance covariance matrix using the method of minimum distance, in targetting the observed moments and minimizing the distance between those and the moments implied by the model. Specifically, we can write the variance-covariance structure

[6]As recommended by Moffitt and Zhang, the initial variance for the transitory component has a factor of c adjustment to it in the estimation to allow for an initial conditions adjustment.

as

$$
\begin{aligned}
\mathrm{var}(y_{iat}) =& \alpha_t^2 \mathrm{var}(\mu_{ia}) + \beta_t^2 \mathrm{var}(\nu_{ia}) \\
\mathrm{var}(\mu_{ia}) =& \mathrm{var}(\mu_{i0}) + \sum_{k=1}^{a} \mathrm{var}(\omega_{ik}) \\
\mathrm{var}(\nu_{ia}) =& \mathrm{var}(\epsilon_{ia}) + \sum_{k=1}^{a-1} \psi_{a,a-s}^2 \mathrm{var}(\epsilon_{i,a-s}) \\
\mathrm{cov}(y_{iat}, y_{i,a-k,t-k}) =& \alpha_t \alpha_{t-k} \Big(\mathrm{var}(\mu_{i0}) + \sum_{j=1}^{a-k} \mathrm{var}(\omega_{ij}) \Big) + \\
& \beta_t \beta_{t-k} \Big(\psi_{a,a-k} \mathrm{var}(\epsilon_{i,a-k}) + \sum_{j=1}^{a-k-1} \psi_{a,a-k-j} \psi_{a-k-j} \mathrm{var}(\epsilon_{i,a-k-j}) \Big)
\end{aligned}
$$

The Role of Information

Alternative Specification

We residualize the income based on a more complete set of information individuals have about what determines their expected earnings. Note the interpretations of the error components decomposition as 'shocks' to individuals' income only holds in the event that the econometrician and the agent observe the same information about individuals' future incomes.

In order to interpret the shocks economically as affecting consumption, one needs a model for how the stochastic process of income would map into consumption decisions.We can think of a household as maximizing the discounted sum of future consumption, subject to the constraints by the usual law of motion

$$\sum_{j=0}^{T} \beta^j (C_{a+j,t+j}) \text{ s.t } A_{a+1,t+1} = (1+r)A_{a+j,t+j} + Y_{a+j,t+j} - C_{a+j,t+j} \tag{4}$$

$$\Delta C_{iat}^{opt} = \pi_a \sum_{j=0}^{\bar{a}} \frac{E(Y_{i,a+k,t+k}|\mathcal{F}_{i,a,t}) - E(Y_{i,a+k,t+k}|\mathcal{F}_{i,a-1,t-1})}{(1+r)^j} \tag{5}$$

Here $\mathcal{F}$ is an individuals information set. Note, that this implies, in the event of no credit constraints, that the changes in consumption are driven purely by changes in the expected income. This also lends itself to the persistence of the shocks to individuals' income. If the shocks fade away over time, they affect the process $E(Y_{i,a+k,t+k}|\mathcal{F}_{i,a,t}) - E(Y_{i,a+k,t+k}|\mathcal{F}_{i,a-1,t-1})$ less than shocks that are supposed be persistent. By adding in the income process in (1), we can also see specifically how the permanent and transitory income shocks map to the changes in consumption with quadratic utility.

Motivated by what is used in the literature (in particular, see Abbott et al. (2019) and Cunha, Heckman and Navarro (2005)), I define the information set as consisting of the individuals' occupation category, five-year age category, gender, years of education, employment status, marital status, number of dependent children, current income decile, and a binary indicator for if the income growth is above or below median.

As proposed by Cunha, Heckman and Navarro (2005). I see whether the information set is rich enough to consider the stochastic deviations as unexpected shocks by testing if deviations in individuals' future expected income, given the present information set, affects individuals' current consumption. Individuals' decisions on what to consume are based off of the information they are aware of. Formally, I test whether $Cov[y_{40} - E(y_{40}|\mathcal{F}_{25}), c_{25}] = 0$. Note, as in Table (**??**), the information set of $\mathcal{F}_{25}$ is able to capture a large amount of the variation that is correlated with individuals' future consumption.

Life-Cycle Events

I break down my samples into individuals that receive the life-cycle shock of divorce at age[7] $\tilde{a} \equiv 35$, and individuals who do not receive the life-cycle shock at any point during the entire period $[a_0, a_T]$. Notationally, I index these samples by r, where $r = 1$ is the sample for whom the event happened (at age $\tilde{a}$) and $r = 0$ is the sample for whom the event did not happen in $[a_0, a_T]$. I am interested in seeing how the advent of divorce impacts individuals' income dynamics. First I see how the large the impact of divorce is on individuals' permanent income, to see how this would map into utility. I can do this through calculating the shock to permanent consumption as per the deviation and calculating the impulse response function for consumption to the shock of divorce consumption in the model (5).

Additionally, I can calculate the permanent-transitory income decomposition entirely separately for

[7] For robustness, I also try an alternative specification of $\tilde{a} = 26$. The results are qualitatively the same

Table 1—: Sufficiency Test for Information set

	$y_{40} - E(y_{40}\|\mathcal{F}_{25})$	y_{40}
c_{25}	-.000	.004
	(-1.04)	(18.36)

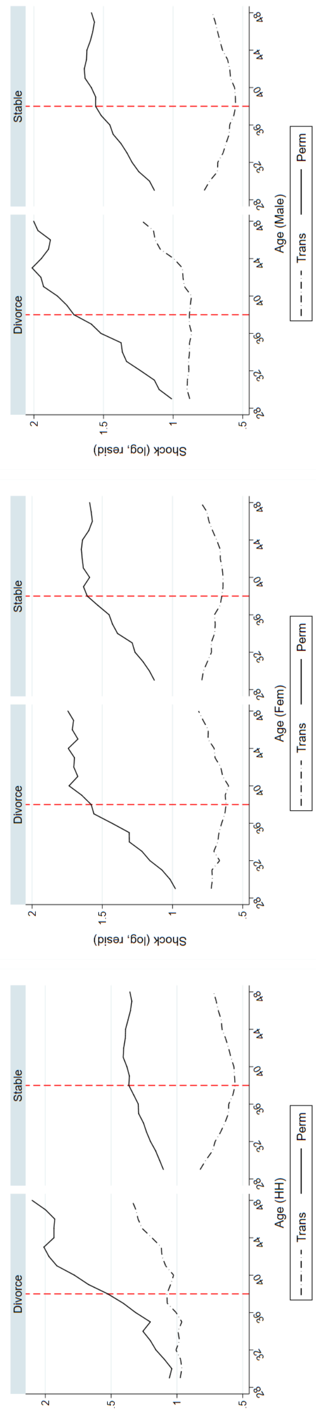
both groups to see if the advent of divorce fundamentally changes the stochastic process for individuals' income dynamics. Concretely, I identify the entire series $\{\theta^r, \{Var(\epsilon^r_{it})\}^T_{t=0}, \{Var(\omega^r_{it})\}^T_{t=0}\}$, so I can see how the permanent shocks $\{\omega^2_{at}\}^{a_T}_{\tilde{a}}$ for individuals who experienced divorce at $\tilde{a}$, $r = 1$, compare with the permanent shocks for individuals who did not experience divorce during the time period, $r = 0$. This can test whether events like divorce can have substantive implications for individuals' stochastic processes, which cannot be adequately represented by a period-specific shock to their income process.

I. Results

Women

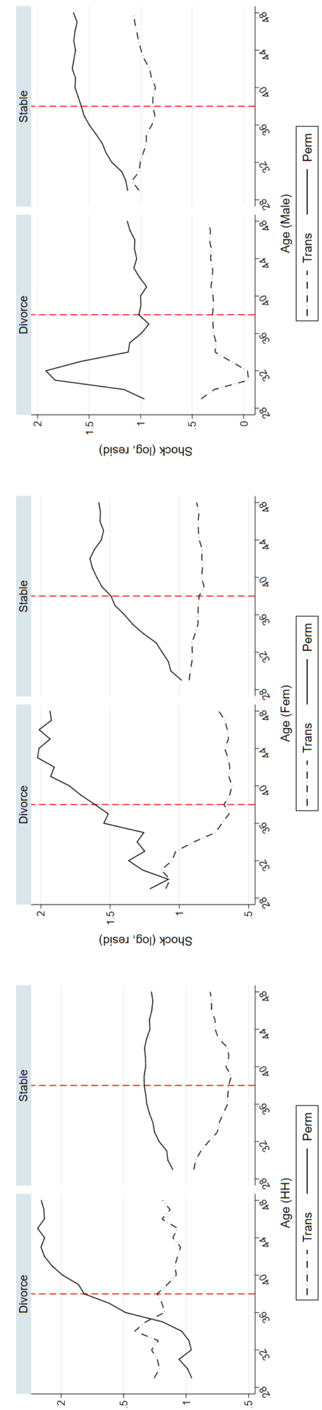
For all the types of income, the trends in permanent and transitory incomes seem quite similar for women before the event of divorce. The notable difference is disposible income, which starts has the fluctuations for the transitory component of the variance start to decline periods before the divorce shock. This is also met partially with increases in the fluctuations for the permanent component increasing before the event of divorce. Concurrently, the estimated permanent shocks seem to be greater a few periods before the shock as well. Wage income in particular also has very similar trends for transitory and permanent income variances after the shock. This seems to also be the case for the income without transfers, though the permanent shocks seem a bit larger after the event for the sample that undergoes divorce. Income with transfers, net of tax income and disposible income look different after the event of divorce for women. There is a noticeable discontinuity around the event of divorce for these resources.

Figure 1. : Trends for Income Without Transfers



(a) HH (b) Women (c) Men

Figure 2. : Trends for Disposable Income



(a) HH (b) Women (c) Men

Income Processes - Results

Table 2—: Estimated Shock to Permanent Component of Divorce

	Income with Transfers	Wage Income
Hhold	1.18	1.03
Female Member	1.70	1.50
Male Member	0.00	1.20

(Estimated shock $E(\omega^2_{\bar{a}t}|r=1) - E(\omega^2_{\bar{a}t}|r=0)$)

Men

For most the types of income, the trends in permanent and transitory incomes are somewhat higher before the event of divorce. The transitory components of the variance seem considerably higher for the wage income and income without transfers before the event of divorce, but the estimated permanent component seem similar before the event across the two samples. The notable difference is disposable income. That seems to have a spike in the permanent component and a corresponding decline in the transitory component in years t-6 - t-4 before the event. After the event, the estimated permanent shocks seem to be greater for most definitions of income,especially in net of tax income and income without transfers. The disposible income is the only one that seems to have a lower permanent and transitory component in the periods ensuing the divorce.

Household

Unsurprisingly, the household variance in the permanent spike the most after the event of divorce for all definitions. There is a a very noticeable change in the trends around the event of divorce in all cases. Again, unsurprisingly, the shift in trends does not happen for the stable sample (r=0). However, the upshot in period-by-period estimates for household income suggest that individuals' resources are fluctuating for a number of periods after the divorce and the dynamics can not be cleanly captures as a single persistent shock around the event. Notably, the large shifts in the shocks are loaded on to the permanent components, suggesting that the shocks that happen after a shock persist.

All

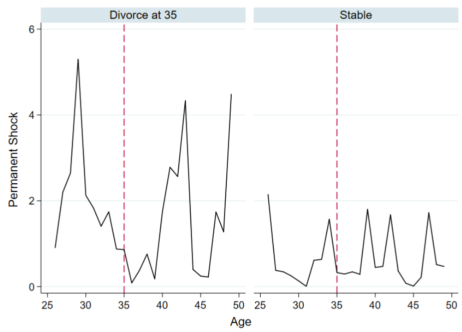
The dynamics in all of these suggest that these life-cycle events may affect individuals' volatility in resources, and that these may operate strongly through transfers and changes in how assets are apportioned as well as the corresponding gains of these assets. The effects are weaker in wage income and income without transfers, but larger when including the role of transfers and capital gains for Income with Transfers and disposible Income. The estimated variances seemed to be higher for the sample that experienced a divorce for a number of periods, which is again consistent with the intuition that individuals receive shocks to their resources around that time and the shocks persist for a number of years. The stark changes in the fluctuation of household resources are also important to note as the resources individuals actually face and borrow against are a combination of both their own resources and their partners' depending on their sharing rules. We mechanically expect (and indeed see) a large increase in volatility at the event of divorce, as the definition of the household itself changes. I go from considering log of the sum of the male head's and the female head's resources to the sum of the male head's family and the female head's family after divorce[8]. This is because, as in the specification (3), the variances for the transitory components after the divorce are estimated with the lags extending to the first period, semi-parametrically[9]. This also suggests with a more variable specification that divorce impacts the general stochastic evolution of the income process.

[8]Whenever they are alone, the family income is their individual income. Whenever they are married or legally cohabiting with another individual, it is the sum of their pooled resources

[9]Note, this might suggest this method may be less suitable to show the periodic effects of a discontinuity in the age-specific variances, as with the life-cycle shock

Figure 3. : Trends for Permanent Shocks - Flexible in age Specification

(a) Income with Transfers



(b) Wage Income

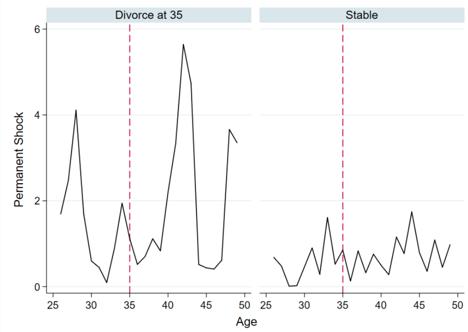
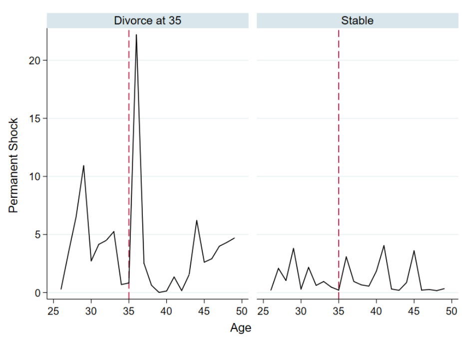
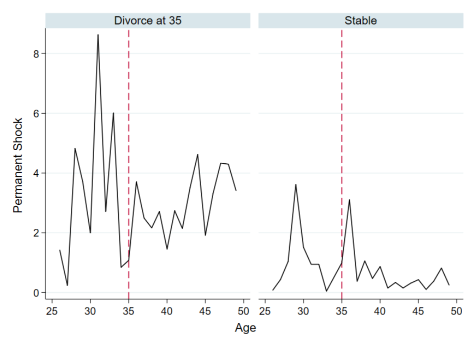


Figure 4. : Trends for Transitory Shocks - Flexible in age Specification

(a) Income with Transfers



(b) Wage Income



Note: This includes the transitory shocks from permanent-transitory income decomposition for residuals from the regression where the permanent and transitory income process is allowed to be influenced by previous shocks, as estimated by an exponential functions of polynomial expansions in age.

II. Simulation

I simulate income processes over ages where people face the empirically estimated earnings processes given their lifecycle events and choose optimal consumption paths. I use CRRA utility with the Aiyagari constraint to get the law of motion and solve with value function iteration

$$\begin{aligned} &\max_{\{c_t\}_1^T,\{A_t\}_1^{T+1}} \sum_{t=1}^{T} \beta^{t-1} u(c_t) \\ &\text{s.t} \qquad c_t + A_{t+1} = A_t(1+r) + L_t \\ &\qquad\qquad A_{t+1} \geq \underline{A}_t, \end{aligned}$$

Uncertainty

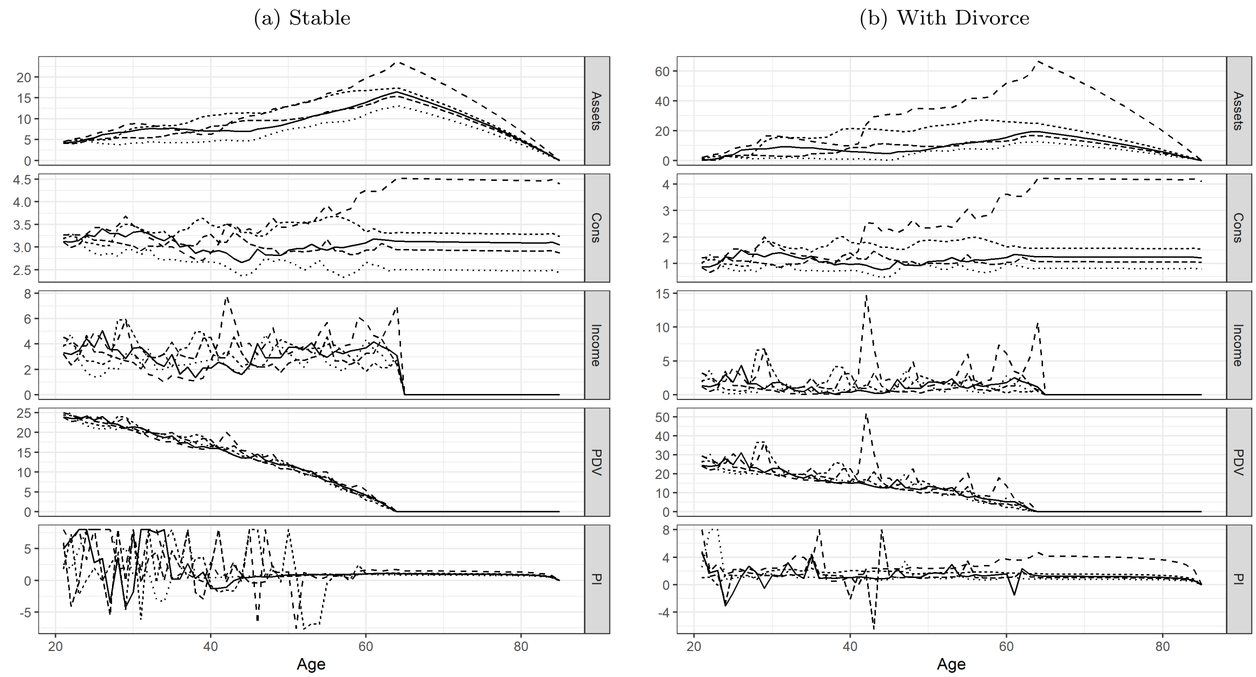
We can have individuals face an stochastic income process, where they get shocks to their income every period and they make decisions on their optimal consumption paths. We have assets, A_t, labor income L_t, and a vector of all shocks in the time period Ω_t.

$$\begin{aligned} V_t\left(A_t, \Omega_t\right) &= \max_{A_{t+1} \in \mathcal{D}_t(A_t, L_t)} \left\{u\left(A_t, L_t, A_{t+1}\right) + \beta \mathbb{E}_t\left(V_{t+1}\left(A_{t+1}, \Omega_{t+1}\right)\right)\right\} \\ \text{s.t. } & c_t + A_{t+1} = A_t(1+r) + L_t \quad \text{ for all } t \end{aligned}$$

Income Process

We simulate profiles for individuals using an autoregressive specification for income shocks with a persistence of ρ. Where $\nu_{it} \sim \mathcal{N}(0, \sigma_\nu)$ and $\alpha_i \sim \mathcal{N}(0, \sigma_\alpha)$ are independently distributed, calibrated to the observed parameters for married and non-married individuals. We also assume that individuals retire at age 65, and $L = 0$ thereafter. The results are shown in Figure (5)[10].

Figure 5. : Simulation results



Note: This involves a simulation of optimal consumption profiles given the income processes estimated for stable (a, left) and divorced (b, right) families.

A. *Results of Simulation*

Conclusion

I find evidence that family dynamics through the dissolution of marriage have an important effect on the stochastic process for individuals income processes. Not only are the estimates for the shocks by such as event substantial, the advent of divorce alters the future evolution of the stochastic process for income. The effects are strongest for pooled household resources and for women, but are substantial for men as well. I investigate this with multiple ways of calculating individuals' unanticipated income, and with multiple specifications for the evolution of the transitory components.

[10] *The full details about the simulation can be accessed via https://github.com/rafehq*

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