Response of Inequality to a Growth Rate Slowdown in Japanese Economy during the Lost Decades*

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Abstract

Japan has experienced a long-lasting slow down of the aggregate output growth over the two decades since the early 1990s, called the lost decades. In this study, we explore how and why cross-sectional moments of Japanese households have changed during the lost decades. We first construct monthly series of variance of log income and consumption and income-consumption correlation from 1981 to 2008 using micro data set on Japanese households from the Family Income and Expenditure Survey (FIES). By making use of structural break test, we ask if these time series have statistically changed over time. We show that the lost decades has come together with a slowdown of income and consumption inequality growth and weakening of income and consumption correlation. Next, we theoretically ask why these changes have occurred. We construct a dynamic general equilibrium model with heterogeneous households with different degree of skills and idiosyncratic income shocks. We show that two factors, a growth rate decline in aggregate TFP and skill biased technology, are the driving forces of changes in cross-sectional moments and aggregate output growth during the lost decades.

Keywords: Income Inequality, Consumption Inequality, Structural Change
JEL Classification: E21, D12, D31

1 Introduction

Japan has experienced a long-lasting slow down of the aggregate economic growth over the two decades since the early 1990s. This period is often called as the lost decades. Figure 1 displays how Japanese economy has changed from the 1980s to the 1990s and beyond. It shows the time path of the key aggregate macroeconomic variables; aggregate households' consumption expenditure, aggregate GDP, aggregate labor compensation, and aggregate TFP, from the 1980s to the current years.[1] The dotted black line depicts the actual growth rate of each macroeconomic variable. The red solid line depicts the estimated mean growth rate of each macroeconomic variable in each sample period. Here the mean is estimated by structural break test that is discussed in later section. The mean growth rates of the four macroeconomic variables have dropped in the early 1990s and never reverted back to the original growth rates of the 1980s in the subsequent years.

In this paper, we explore how cross-sectional moments across Japanese households have changed with the aggregate economic slowdown characterized by the downward shifts in the mean growth rates of aggregate macroeconomic variables during the early 1990s. The cross-sectional moments include variance of log income and consumption as well as income-consumption correlation across Japanese households. We first construct a set of cross-sectional moments using the micro data survey on Japanese households, *the Family Income and Expenditure Survey*. We then apply structural break test proposed by Bai and Perron (1998) to these constructed series. The test allows us to pin down the number, timing, and size of the breaks in these series by statistical inference. There are three noteworthy observations: (*i*) The lost decades has come together with permanent slowdown of income and consumption inequality growth rate. That is, income and consumption inequality have grown at lower rates during the 1990s and beyond compared with the 1980s. (*ii*) Slowdown of income inequality growth during the early 1990 is mostly attributed to a disproportionately large slowdown of income growth rate of high-income households. (*iii*) The linkage between income and consumption has weakened during the 1990s and beyond compared with the case during the 1980s.

In order to examine causes of the changes in observed cross-sectional moments, as well as aggregate economic slowdown, we develop a dynamic general equilibrium model. In our model, households are subject to idiosyncratic income shocks and therefore differ from each other in terms of their income profiles. In addition, households are different in terms of degree of skills attached to their labor inputs. That is, one type of households supply skilled labor inputs to firms and the other type of the households supply unskilled labor inputs to firms. Firms produce output from the two types of labor inputs as well as capital inputs supplied from households. We then examine the linkage between two kinds of technology, aggregate technology and technology that enhances productivity

[1] The four series are shown on a year-to-year growth rate basis.

of skilled labor inputs–skill biased technology–and the cross-sectional moment across households. We consider two cases, a case where aggregate technology growth slows down and a case where skilled biased technology growth slows down and we study if the two growth rate slowdowns may account for the three observations discussed above.

Based on the model calibrated to the Japanese economy, we show that growth rate slowdown of both technologies are needed to fully account for changes in the cross-sectional moments observed in the data. Growth rate slowdown of aggregate technology is silent about income inequality but it lowers consumption inequality and income-consumption relationship across households. The latter effect comes from decreases in households who are subject to borrowing constraints. Note that when its expected income growth falls, a household spends less and its borrowing constraint ceases to bite. In the aggregate, therefore income-consumption correlation falls and consumption inequality shrinks. Growth rate slowdown of skilled biased technology trivially lowers growth rate of income and consumption inequality. It however, increases income-consumption correlations as consumption of households with skilled labor inputs becomes more responsive to income profiles.

A good number of studies have already explored the linkage between aggregate macroeconomic activity, such as recession or expansion, and developments of inequality. For instance, Krueger et al. (2010) summarize common features of developments in inequality in nine countries and document that earning inequality appears to be strongly counter-cyclical. Storesletten et al. (2004) conduct GMM using annual panel data of Panel Study on Income Dynamics (PSID) to extract cyclicality of idiosyncratic labor market risk and report that the risk is strongly countercyclical. In addition to these studies, our study is related to works that focus on the role of skill biased technology in generating income inequality. For instance, Katz and Autor (1999) discusses that a large part of the rising wage inequality observed in the U.S. is explained by the returns to observed/unobserved skills and education attainment. Relatedly, Acemoglu (2002) theoretically shows that rapid increase in skill biased technology may lead to widening of income inequality.

In contrast to these existing studies, our study is novel in two aspects. First, our study focuses on the effects on inequality of a permanent slowdown of economy or decades-long recession that has lasted longer than ordinary business cycle. In this aspect, our study is close to the work by Meyer and Sullivan (2013) that focus on the impact of the current Great Recession on income and consumption inequality in the U.S. Second, our monthly time series of inequality allows us to conduct structural break test to the inequality data. We therefore able to pin down when and how changes in inequality have changed.

The structure of this paper is as follows. Section 2 explains our micro data set and construction methodology of time series used in our analysis. It also empirically investigates when and how households income, consumption, and the correlation between the two variables have evolved during the last three decades. Section 3 describes our model settings. Section 4 describes our model calibration. Section 5 discusses our simulation analysis. Section 6 concludes.

2 Time-series Properties of Inequalities before and during the Lost Decades

In this section, we empirically explore when and how time series properties of inequalities have changed. We examine the mean value, the variance of logarithm, and covariance/correlation between variables of the monthly time series data by making use of an econometric framework that allows for multiple structural breaks during the sample period and study the date and size of the breaks. In particular, we focus on the difference of the mean value of the time series before and during the lost decades.

2.1 Data

To conduct the time-series analysis on economic inequalities, we construct a monthly time series of variance of logarithm of earnings and consumption as well as mean of income and consumption of households that are categorized by their characteristics. The time series is constructed from the micro data survey, *the Family Income and Expenditures Survey* (hereafter FIES), that is compiled and released by the Statistics Bureau, Ministry of Internal Affairs and Communications in Japan.[2]

The FIES is a monthly diary survey that collects earnings, income and expenditures of Japanese households and reports characteristics of sampled households including household members' ages, gender, occupation, industry of employment, marital status, and region of residence. The survey reports monthly labor income of household head, spouse and the sum of other household members Unfortunately, the FIES does not collect information about education, which prohibits us to estimate college premium directly from the FIES. The consumption expenditures include food, services, nondurable, semidurable and durable expenditures. The survey was first conducted in 1953. However, we have access only to data for the period from January 1981 to December 2008 for the purpose of the current research. We use data of multi-person households only because the data of single-person households is available only after 2002. The survey contains approximately 8,000 households per month. Surveyed households reports monthly earnings and expenditures for a maximum of six consecutive months. The sampled households overlap, and one-sixth of the total sample is generally replaced by new

[2] FIES is a source data of the households' expenditures weighting used to construct Consumption Price Index. FIES is also a primary source data of Private Consumption series in GDP that is compiled and published from the Cabinet Office.

households each month.

We closely follow Lise, et al. (2014), in which they study the evolution of economic inequality of Japanese economy from the boom time including the bubble period of late 1980s to the lost decades, in constructing the time series of inequality measures and means. The key difference between Lise, et al. (2014) and our study is that we employ the monthly series instead of annual series. The monthly inequality series exhibit seasonality reflecting seasonal variations in households' income and consumption at the micro level. In particular, the bonus payment, which is typically paid twice in a year, in June (or July) and December, makes strong seasonality for labor income. To obtain the seasonally adjusted series, we first construct the seasonally unadjusted monthly series and apply X12 ARIMA to these series.

We focus on the monthly series of before-tax equivalized household labor income y_L and nondurable expenditure c_{ND}.[3] The household labor income is calculated as the sum of labor earnings of household head, spouse and other household members, and it is equivalized using the OECD equivalent scale. We restrict the usage of data set to households with *employed* household head aged 25–59, because it is difficult to measure monthly income of self-employed workers. Both rising unemployment rates and increasing number of non-standard workers such as contingent workers and part-time workers undoubtedly contribute recent trend of rising inequality of Japanese economy. In regard to this point, our estimates may underestimate the true whole inequality. However, even if we focus on the employed household, the trend in economic inequality appears positive. We use nondurable expenditures as consumption to be consistent with consumption smoothing.[4] That is, housing, purchasing cars and durable expenses such as furniture are excluded. Every variables are deflated to the 2005 price using the CPI.

2.2 Econometric Methodology for Identifying Breaks

Before documenting the time series properties of inequality, we briefly describe the econometric methodology. The analytical framework is borrowed from the early work by Bai and Perron (1998). Following Bai and Perron (1998) (1998), for each of the monthly time series which we analyze ξ_t for $t = 1, ..., T$, we consider the following multiple linear

[3]We have also conducted the time series analysis on disposable income, and we confirmed that our main results do not change even if we use disposable income.

[4]For the detailed definition on nondurable expenditure, see Lise, et al. (2014).

law of motion with m number of breaks ($m+1$ breaks).

$$\begin{aligned}
\xi_t &= x_t\beta + u_t, \text{ for } t = 1, ..., T_1, \\
\xi_t &= x_t\beta + z_1\delta_1 + u_t, \text{ for } t = T_1+1, ..., T_2, \\
&\vdots \\
\xi_t &= x_t\beta + \sum_{j=1}^{l} z_l\delta_l + u_t, \text{ for } t = T_l+1, ..., T_{l+1}, \\
\xi_t &= x_t\beta + \sum_{j=1}^{m} z_j\delta_j + u_t, \text{ for } t = T_m+1, ..., T,
\end{aligned} \tag{1}$$

where $x = \{x_t\}$ is a $T\times$ 1 vector whose elements are all unity and z_j is a variable that takes zero for $t \leq T_j$ and takes unity in the period beyond T. β and δ_j for $j = 1, ..., m$ are corresponding parameters. The indices $(T_1, ..., T_m)$ are break dates. They are unknown and to be estimated as well. u_t is the disturbance at period t.

Using the time series of ξ_t from January 1981 to December 2008, we estimate a period $(T_1, ..., T_m)$ and the break size δ_j. In determining the number of breaks, we follow Bai and Perron (1998) and consider a test for the null hypothesis that there are no structural breaks in the sampled period against an alternative hypothesis that there is a structural break, or against the alternative hypothesis that there are j number of structural breaks for $j = 1, 2, ..., m$. Throughout the paper, we assume that the maximum number of breaks m is equal to or less than 5.

2.3 Income and Consumption Inequality

We start with describing the developments of inequality before and during the lost decades. Figure 2 displays the time path of income and consumption inequality across households. The inequalities are measured by the variance of log of equivalized disposable income and equivalized non-durable consumption expenditure which we denote by $var(\log(y_{i,t}))$ and $var(\log(c_{i,t}))$ respectively. The upper panel of the figure displays the level of inequalities, that is $var(\log(y_{i,t}))$ and $var(\log(c_{i,t}))$, and the lower panel of the figure displays the year-on-year difference of inequalities, that is $var(\log(y_{i,t})) - var(\log(y_{i,t-12}))$ and $var(\log(c_{i,t})) - var(\log(c_{i,t-12}))$. The dotted black lines depict the actual time path ξ_t and the red solid lines depict the estimated mean, which is $x_t\beta + \sum_{j=1}^{l} z_l\delta_l$, of the series in period $t = T_l + 1, ...T_{l+1}$. In both of the level and growth specifications, it is seen that income and consumption inequality have a positive trend over the sample period. In addition, the two inequalities grow at a slower pace during the 1990s and beyond compared with the pace during the 1980s. For instance, regarding the level of variance of log income, the inequality has risen from 0.26 in the early 1980s to 0.33 in 2008, the bulk of the difference in the number is attributed to the breaks that have occurred until the early 1990s. The similar picture is observed for the comparable series for consumption. Clearly, the lost decades is accompanied by the slowdown of income inequality growth and such slowdown is to some extent transmitted to the slowdown of consumption income growth.

2.4 Breakdown of Income Inequality Growth

In order to see the background behind the slowdown of income and consumption inequality, we compare the income and consumption profile of households with different characteristics. Our measure of characteristics includes household's head's income level quantile, occupation of household's head, industry of household's head job, and household's head age. For each of the measures, we divide households into subgroups according to their profiles and construct the time path of the mean of the income and consumption by taking average across households. We then apply the structural break tests to the year-on-year growth rate of the mean series of each subgroup household.

Table 1 and 2 display the estimation results of the structural break tests for the mean income and mean consumption, respectively. The first three columns stand for the first, second, and third break dates that have taken place in the mean series of each subgroup.[5] The fourth column stands for the average growth rate, which corresponds to β in equation (1). The last three columns stand for the size of the first, second, and third structural break in terms of year-on-year growth rate. The two observations are noteworthy related to the mean income growth. First, mean income growth grows at different rate across households that have distinct profiles. For instance, regarding occupation, mean income growth of temporary worker is strictly lower than that of other subgroups. Second, most of the subgroups have witnessed downward structural break around the period of the bubble burst and beyond and size of the break differs across subgroups. At least the analysis regarding income quantile is concerned, the two observations provide possible explanations as to why growth rate of income inequality has slowed down after the early 1990s. Among subgroups categorized by income quantiles, the subgroup of upper-quantile-households witnesses higher mean income growth than those of lower-quantile-households throughout the period. During the early 1990s, only the two highest subgroups see the downward structural break in their mean income growth rate while the rest of the households do not see the breaks. In particular the break size is larger for the highest subgroup. Clearly, such asymmetric breaks soften income inequality growth. During the late 1990s, lower-quantile-household see the downward break as well but their quantitative size is minor.

[5] Note that though we set that the maximum number of the breaks is five throughout the estimations, the number of breaks detected in these series are two at the largest.

2.5 Transmission from Income Inequality to Consumption Inequality

We show in Figure 2 that breaks in income inequality are to some extent translated to consumption inequality. Here we further analyze the transmission by computing correlation between income and consumption. Figure **??** displays the time path of contemporaneous covariance between income and consumption $var\left(\log\left(y_{i,t}\right),\log\left(c_{i,t}\right)\right)$, corresponding correlation between income and consumption, contemporaneous covariance between income growth and consumption $var\left(\log\left(y_{i,t}/y_{i,t-1}\right),\log\left(c_{i,t}/c_{i,t-1}\right)\right)$, corresponding contemporaneous correlation between income growth and consumption, and variance of consumption growth $var\left(\log\left(c_{i,t}\right)/\log\left(c_{i,t-1}\right)\right)$. The structural break tests are applied to all of the series and estimated means are depicted in red solid line. There are signs for the weakening of transmission from income to consumption over the sample period. For instance, the correlation between level of income and consumption is positive but has lowered by about 0.1 from the 1980s to the 1990s and beyond.

3 Model

We provide a quantitative models that account for the empirical findings documented in Section 2. To this end, we develop an incomplete-market overlapping-generations model so as to identify the transmission mechanism from the slowdown of the aggregate economy to the inequality across households. In particular, we focus on the following empirical observations: (i) simultaneous slowdown of mean growth rate of aggregate GDP and that of inequality growth rate and (ii) weakening of the transmission from income variations to consumption variations.

Demographics: There is a continuum of households that faces survival risk s_{j+1}, which denote the conditional survival probability from the age j to $j+1$. Denote the population size of age j as μ_j. Then the population size transits from the following equation:

$$\mu_{j+1}=\frac{s_{j+1}}{1+n}\mu_j,$$

where n is a population growth rate. We normalize the total population to be one, i.e.,$\sum_{j=1}^{J}\mu_j=1$. We assume that the population distribution is constant over time.

Household: There is a continuum of households who retire at the age of j^{ret}, and lives at most J. Denote calender time t. There are two types of households, those with skilled labor input s and those with unskilled labor input u. Households face idiosyncratic labor productivity risks in their working age. The labor income consists of the macroeconomic wage level w_t^e, which differs by skill type $e\in\{s,u\}$, the age-specific efficiency κ_j^e, the persistent component of labor productivity shock η and the purely transitory shock ε:

before-tax labor income is determined by $y_{j,t} = w_t^e \kappa_j^e \eta \varepsilon$. The government imposes labor income tax τ^y on the labor income, and it also collects social security benefit from the labor income as a payroll tax τ^{ss}. After retirement, households receive public pension ss from the government. We assume that the public pension benefit is constant across the same type of households, although they may have different realizations of past labor income and, as a result, different public pension contribution. We also assume that the public pension benefit is a constant fraction of the average earnings at period t, $\bar{L}^e = \sum_{j=1}^{j^{ret}} y_{j,t}/j^{ret}$, by skill type. Denoting the replacement rate as ϕ, the pension benefit is written as $ss = \phi w_t^e \bar{L}_t^e$.

The household problem is defined as follows:

$$V_{j,t}^e(a_{j,t}, \eta, \varepsilon) = \max_{c_j, a_{j+1}} u(c_{j,t}) + s_{j+1}\beta \mathbb{E}\left[V_{j+1,t+1}^e(a_{j+1}, \eta', \varepsilon')\right], \tag{2}$$

subject to

$$c_{j,t} + a_{j+1,t+1} = \tilde{y}_{j,t} + (1 + (1-\tau^k) r_t)(a_{j,t} + b_t), \tag{3}$$

$$\tilde{y}_{j,t} = \begin{cases} (1 - \tau^y - \tau^{ss}) w_t^e \kappa_j^e \eta \varepsilon & \text{if} \quad j \leq j^{ret}, \\ \phi w_t^e \bar{L}_t^e & \text{if} \quad j > j^{ret}, \end{cases}$$

$$a_{j+1,t+1} \geq 0.$$

where $c_{j,t}$ is consumption at age j and time t, $a_{j,t}$ and $a_{j+1,t+1}$ are current and next period's savings, and b_t is an accidental bequest. The accidental bequests are collected by the government and redistributed by the lump-sum manner. The financial asset yields return r_t although the capital income tax τ^k is imposed on the asset income $r_t(a_{j,t} + b_t)$. We assume that households face the borrowing constraint, $a_{j+1,t+1} \geq 0$.

Aggregation: Aggregate labor inputs of both types of workers are defined as population-weighted sum of heterogeneous households:

$$L_t^e = \sum_{j=1}^{j^{ret}} \mu_j \int \kappa_j^e \eta \varepsilon d\Psi_{j,t}^e(a, \eta, \varepsilon), \quad e \in \{s, u\}, \tag{4}$$

where $\Psi_{j,t}^e(a, \eta, \varepsilon)$ is the density function of age j over the state variables (a, η, ε).

Skilled and unskilled labor inputs are combined using the following aggregator function:[6]

$$L_t = \left[(A_t^s L_t^s)^\rho + (A_t^u L_t^u)^\rho\right]^{\frac{1}{\rho}}, \quad \rho \leq 1, \tag{5}$$

where A_t^s and A_t^u are factor augmenting technologies for skilled and unskilled aggregate labor inputs, respectively. The parameter $\frac{1}{1-\rho}$ determines the elasticity of substitution between two types of labor input.

[6] For details, see Heckman et al. (1998), Acemoglu (2002), and Heathcote et al. (2010).

Aggregate capital is defined as population-weighted sum of household savings:

$$K_t = \sum_{j=1}^{J} \mu_j \int a d\Psi^e_{j,t}(a,\eta,\varepsilon). \tag{6}$$

A representative firm combines the aggregate capital and labor for production using the standard Cobb-Douglas type technology:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha},$$

where the TFP factor grows with $1 + g_t = \frac{A_{t+1}^{1/(1-\alpha)}}{A_t^{1/(1-\alpha)}}$. As will be discussed in Section 4, we allow both the TFP factor growth rate g_t and the demand for skilled and unskiled labor $\{A^s, A^u\}$ varies over time.

Equilibrium wages are determined from the first order conditions:

$$w^s_t = (1-\alpha)A_t \left(\frac{K_t}{L_t}\right)^{\alpha} L_t^{1-\rho}(A^s_t)^{\rho}(L^s_t)^{\rho-1}, \tag{7}$$

$$w^u_t = (1-\alpha)A_t \left(\frac{K_t}{L_t}\right)^{\alpha} L_t^{1-\rho}(A^u_t)^{\rho}(L^u_t)^{\rho-1}. \tag{8}$$

As both equations suggest, the skilled/unskilled wages are affected by the skill demand and labor supply of skilled and unskilled workers.

Government: The government collect taxes through labor income τ^y and capital income τ^k, and the tax revenues are used for the government expenditure which yields no utility for households.

$$G_t = \tau^y \sum_{e\in\{s,u\}} \sum_{j=1}^{j^{ret}} \mu_j \int w^e_t \kappa^e_j \eta\varepsilon d\Psi^e_{j,t}(a,\eta,\varepsilon) + \tau^k \sum_{e\in\{s,u\}} \sum_{j=1}^{J} \mu_j \int r_t a d\Psi^e_{j,t}(a,\eta,\varepsilon). \tag{9}$$

The accidental bequests are distributed to survived households as lump-sum transfer:

$$b_t = \sum_{j=1}^{J} \mu_j \int (1-s_{j+1}) g^a_t(a,z,j) d\Psi_{j,t}(a,z,\xi), \tag{10}$$

where $a_{j+1,t+1} = g^a_t(a,z,j)$ is a policy function for each household. Given the payroll tax rate τ^{ss}, the government set the replacement rate ϕ endogenously to satisfy the following budget constraint:

$$\sum_{e\in\{s,u\}} \sum_{j=1}^{j^{ret}} \mu_j \int \tau^{ss} w^e_t \kappa^e_j \eta\varepsilon d\Psi^e_{j,t}(a,\eta,\varepsilon) = \sum_{e\in\{s,u\}} \sum_{j=j^{ret}+1}^{J} \mu_j \int \phi w^e_t \bar{L}^e_t d\Psi^e_{j,t}(a,\eta,\varepsilon). \tag{11}$$

Equilibrium: The economy is initially in a steady state with high TFP factor growth rate and a set of skill demand $\{A^s, A^u\}$ that match Japanese economy in 1980s. Unexpectedly, households find that the TFP factor growth and/or skill demands changes at period 0, and it continues forever. In the benchmark case, we assume that all households understand that the growth rate drop happened at period 0. Thus, we compute transition paths between the initial steady state with high growth and the final steady state with low TFP growth.

Definition (Recursive Competitive Equilibrium): Given the exogenous paths of TFP factor growth rate g_t, and factor augmenting technologies for skills $\{A^s_t, A^u_t\}$, the recursive competitive equilibrium is a set of the policy functions $\{g^a_{j,t}\}$, aggregate capital $\{K_t\}$, factor prices $\{r_t, w^s_t, w^u_t\}$, replacement rate ϕ, and accidental bequests $\{b_t\}$ that satisfy the following conditions:

- Household optimality: Given factor prices $\{r_t, w^s_t, w^u_t\}$ and tax rates $\{\tau^y, \tau^k, \tau^{ss}\}$, a household maximizes its expected utility, and the functions $\{g^a_{j,t}\}$ is the associated policy functions.
- Firm optimality: Factor prices are competitively determined using equation (7) and (8).
- Market clearing: The market clearing conditions expressed in equation (6) and (5) are satisfied.
- Government budget: The government budget constraints expressed in equations (9) and (11) are satisfied.
- Accidental bequests: Accidental bequests are redistributed in accordance with equation (10).
- Transition law of motion: The distribution function $\Psi^e_{j,t}(a, z, \xi)$ transits consistently with the policy functions.

Following Conesa and Krueger (1999), we first compute the initial and final steady states, and then compute the transition path between them.

4 Calibration

4.1 Demographics

We calibrate the demographics of the model to match the actual population distribution in Japan in 2010. The survival probabilities $\{s_j\}_{j=1}^J$ are taken from the estimates by the National Institute for Population and Social Security Research, and the population growth rate n is set to 0 to match the actual population distribution.

4.2 TFP Factor Growth Rate

The TFP factor growth rates are the key in our setup. As is well known from the research by Hayashi and Prescott (2002), the TFP factor growth rate sharply declined after 1990s, which is a main cause of long stagnation in 1990s called the lost decade. Muto, et al. (2013) also estimate the TFP growth rate from SNA. In the estimates by Muto et al. (2013), although the average TFP growth rate in 1980s was 1.84%, it declined to 0.42% in 1990s. Facing with the huge decline of the TFP growth rate in the period of the great recession in 2009, the average TFP growth rate has further dropped to 0.16% in 2000s. We assume that, in the initial steady state with high growth rate, the TFP growth rate is set at 1.89%, but it drop to 0.16% from period 0 to period 1. The low TFP growth rate continues from period 1 to the final steady state.

4.3 Preferences and Production Function

Preference parameters are determined as follows. The subjective discount factor β is set at 0.99, and inverse of intertemporal elasticity of substitution parameter γ is set at 2. These values are standard in the literature. As will be shown later, capital-to-output ratio, K/Y, ranges between 2 and 2.5 in the benchmark model using these parameters. We use estimates by İmrohoroğlu and Sudo (2011) to set capital share parameter α and depreciation rate δ: $\alpha = 0.377$ and $\delta = 0.08$ respectively.

4.4 Idiosyncratic Income Risks

We set idiosyncratic income risks parameters following on Lise et al. (2014). Log of the persistent component of the labor income follows AR(1) process as follows:

$$\ln \eta_{j+1} = \lambda \ln \eta_j + \omega_j, \quad \omega \sim \mathcal{N}(0, \sigma_\omega^2),$$

where λ determines persistence of the shock and σ_ω^2 is the shock size. The transitory shock is purely i.i.d. shock and follows log-normal distribution:

$$\ln \varepsilon \sim \mathcal{N}(-\sigma_\varepsilon^2/2, \sigma_\varepsilon^2).$$

Hayashi and Prescott (2002)) estimate the sizes of permanent and temporary shocks from Japanese Panel Survey of Consumers. In their estimation, both the permanent and transitory shocks are time-varying parameters and the persistence of permanent shock is one. Since Yamada (2012) shows that the persistence parameter λ is very close to 1, we set λ at 0.97. From Figure 6.1 in Lise et al. (2014), the average of variances of permanent shock in Japan is approximately 0.01 from 1993 to 2005. Thus, we set σ_ω^2 at 0.01. From the same figure, the variance of transitory shock σ_ε^2 is about 0.03.

The AR(1) process is approximated by finite Markov chain using Rouwenhorst (1995)'s approximation method.[7]

The age-efficiency profiles $\{\kappa_j^e\}_{j=1}^{jret}$ are estimated from the Basic Survey on Wage Structure.[8] For each of the age-efficiency profile of skilled and unskilled workers, we use wage of college graduate and high school graduate workers respectively.

4.5 Skill Premium

The factor augmenting technologies that determines the skill prices are calibrated to match the data following the approach by Acemoglu (2002). In particular, using the Basic Survey on Wage Structure, we compute

$$\frac{A^s}{A^u} = \frac{S_H^{\zeta/(\zeta-1)}}{L^s/L^u},$$

where $S_H = \frac{w^s L^s}{w^u L^u}$ is the ratio of the wage bill. Following Heathcote et al. (2010), $\zeta \equiv \frac{1}{1-\rho}$, which is the elasticity of substitution, is set at 1.4. We use total hours worked, which is the product of the number of employees and the monthly actual number of scheduled hours worked, to compute L^s and L^u respectively.

Calibrated parameters are summarized in Table 3.

5 Simulations

5.1 Simulation Exercise

Based on our model calibrated to Japanese economy, we conduct two experiments and examine effects of the technology growth slowdown on income and consumption inequality and the correlation of log income and consumption. In the first experiment, we study a case where TFP growth rate unexpectedly drops from g_H to g_L in period T_1 and beyond. That is,

$$\frac{A_{t+1}}{A_t} = \begin{cases} g_H & \text{for} \quad t < T_1, \\ g_L & \text{for} \quad t \geq T_1. \end{cases}$$

In preceding studies that explore causes of the lost decades, including Hayashi and Prescott (2002) and Muto et al. (2013), growth rate decline in TFP is considered as the key source of output stagnation. In conducting the first exercise, we aim to investigate its impact on cross-sectional moments of households as well as aggregate variables.

[7]For details, Kopecky and Suen (2010). We choose the number of state for z at 9. The transitory shock is approximated based on Gaussian quadrature points, and the number of approximated point is 5.

[8]For details, see Braun et al. (2009).

Figure 7 reports the transition paths of TFP growth rate, skill premium, after-tax interest rate, and capital stock in the wake of unexpected change in TFP growth rate. Note that we set $T_1 = 1$. As shown in the panel (b), the skill premium is unaffected by the TFP decline as wages of both skilled and unskilled labor inputs respond to the decline symmetrically. As shown in the panel (c), the after-tax interest rate gradually decreases after the decline of TFP growth rate. A lower growth rate of TFP drives down the real return on capital investment. In addition to this direct effect, an increase in capital stock due to higher saving of households help decrease interest rate. Figure 8 reports the transition path of variance of log income and that of log consumption. Note that in this experiment, we only alter TFP growth rate g and maintain other parameters, including the variance of log income σ_ω^2 and σ_ε^2, constant. It is shown that the variance of log income does not respond to the change in TFP growth rate and evolves around the same level before and after the impact period $T_1 = 0$. The variance of log consumption drops at the period when TFP growth rate falls and remains stable at the law level afterwards. Figure 9 displays the four measures of income-consumption linkage, the covariance and correlation of log income and log consumption and those of log differences of income and consumption. All of the four measures fall in response to the decline in TFP growth rate.

In the second experiment, we study a case where growth rate of factor augmenting technology for skilled labor inputs A_t^s increases from a growth rate g_L^s to a growth rate g_H^s in period $t = T_1$ and stays at the rate for a length or period until period $t = T_2$ and reverts back to the original growth rate g_L^s in period $t = T_2 + 1$ and beyond. That is,

$$\frac{A_{t+1}^s}{A_t^s} = \begin{cases} g_L^s & \text{for} \quad t < T_1, \\ g_H^s & \text{for} \quad T_1 \leq t \leq T_2 \\ g_L^s & \text{for} \quad t > T_2 \end{cases}$$

As shown in Section 2, our data facts indicate that widening of income inequality during the 1980s was attributed to a rapid income increase of upper-quantile households. Since the early 1990s, the increase has been moderate compared with the previous years and differential of income growth across households has been reduced. This exercise aims to capture such movements of income growth differentials across households.

Figures 10–15 report simulation results for the second experiment.

Figure 10 reports the transition paths of TFP growth rate, skill premium, after-tax interest rate, and capital stock in the wake of unexpected change in skill biased technology growth rate. Note that we set $T_1 = 1$ and $T_2 = 10$. As shown in the panel (b), the skill premium widens permanently by the short-run acceleration of growth rate of skill biased technology. This reflects the fact that wage for skilled labor inputs increases by a disproportionately large amount while wage for unskilled labor inputs is little affected by the changes in skilled biased technology. As shown in the panel (c), the after-tax interest rate increases in the short-run and gradually reverts back to the original level. Figure 11 reports the transition path of variance of log income and that of log consumption. It is seen that the variances of log income and consumption increase following the change in skilled biased TFP growth rate over the period from T_1 to T_2 and remain at the high value in the subsequent period. Figure 15 displays the four measures of income-consumption linkage. The changes in skilled biased technology bring about different impacts on income-consumption linkage in level and in growth rate. That is, the covariance and correlation of log income and log consumption increase over the period from T_1 to T_2 and remain at the high value in the subsequent period. By contrast, the covariance and correlation of log differences of income and consumption is barely affected by the changes in skilled biased technology.

5.2 Model Mechanism

In this subsection, we discuss channels through which growth rate slowdowns of TFP A_t or factor augmented technology for skilled labor inputs A_t^s affects income and consumption inequality as well as income-consumption linkages.

Slowdown of growth rate of labor income inequality We first show that a decline in the growth rate of TFP A_t does not affect income inequality. To see this, we arrange equations 7 and 8 into the following equation:

$$var\left(\ln\left(y_t\right)\right) = \sum_{e=s,u}\left(\int d\Psi^e_{j,t}(a,\eta,\varepsilon)\right)\left(\ln\left(\frac{(A^e_t)^\rho L^e_t}{\sum_{e=s,u}\left(\int d\Psi^e_{j,t}(a,\eta,\varepsilon)\right)(A^e_t)^\rho\left(L^e_t\right)}\right)\right)^2 \tag{12}$$

where

$$\Phi^e = \int d\Psi^e_{j,t}(a,\eta,\varepsilon) \text{ for } e = s \text{ and } u.$$

It is clear from equation (12) that the variance of log labor income is independent from TFP as A_t does not appear in this equation.

By contrast, there is transmission mechanism from the growth rate of factor augmenting technology for skilled labor inputs A_t^s to the income inequality. Provided that the term $(A_t^s)^\rho L_t^s$ is greater than the term $(A_t^u)^\rho L_t^u$, which is the case in our model, the equation (12) indicates that the variance of log labor income increases with the gap between the two terms $(A_t^s)^\rho L_t^s$ and $(A_t^u)^\rho L_t^u$. These implications are consistent with what are shown in Figure 8 and Figure 11.

Slowdown of consumption inequality growth Next, we show the relationship between the technology growth slowdown and consumption inequality. To this end, for illustrative purpose, we construct a stylized two-period model and discuss how changes in aggregate TFP and technology for skilled labor inputs are translated to households' consumption.[9] In our two-period model, The utility maximization problem for household j is written as follows.

$$\begin{aligned} \max_{c_{j,1},c_{j,2},a_{j,2}} \quad & u(c_{j,1}) + \beta u(c_{j,2}) \\ \text{subject to} \quad & c_{j,1} + a_{j,2} = y_{j,1} + a_{j,1} \\ & c_{j,2} = y_{j,2} + (1+r)a_{j,2} \\ & a_{j,1} \text{ given} \\ & a_{j,2} \geq 0 \\ & c_{j,1}, c_{j,2} \geq 0 \end{aligned}$$

Let $y_{j,2} = gy_{j,1}$. The coefficient g represents a (gross) rate of income growth. When TFP growth rate is considered, g is common to all households. When growth rate of skilled labor inputs is considered, households with skilled labor inputs commonly witness the growth rate g^s and those with unskilled labor inputs witness the growth rate g^u. The utility function $u(c_{j,t})$ is defined by $u(c) = \frac{(c_{j,t})^{1-\gamma}}{1-\gamma}$. Let $x_{j,1}$ denote cash-on-hand in period 1, that is, $x_{j,1} = y_{j,1} + a_{j,1}$. The solution to the household problem is as follows.

$$c_{j,1} = \begin{cases} \left(\frac{1+r}{1+r+\Gamma}\right)\left(x_{j,1} + \frac{1}{1+r}y_{j,2}\right) & \text{if } \Gamma x_1 \geq g y_1 \\ x_{j,1} & \text{otherwise,} \end{cases}$$

where $\Gamma = (\beta(1+r))^{\frac{1}{\sigma}}$.

We start with the analysis on how aggregate TFP growth A_t/A_{t-1} is translated to the consumption inequality. We show that though changes in aggregate TFP growth do not affect labor income inequality, they may affect consumption inequality. To see this, we study a case when $a_{j,1} = 0$ for all households (case 1) and a case when $a_{j,1} > 0$ for all j.

Case 1: Suppose that $a_1 = 0$ for all households. In this case, $x_1 = y_1$. Then,

$$c_1 = \begin{cases} \frac{1+r+g}{1+r+\Gamma} y_1 & \text{if } (\Gamma - g)y_1 \geq 0 \\ y_1 & \text{otherwise} \end{cases}$$

If $\Gamma \geq g$ (or, $(\beta(1+r))^{\frac{1}{\gamma}} \geq g$), then the borrowing constraint does not bind for all households, while if $\Gamma < g$, then the borrowing constraint binds for all households. But the variance of $\ln c_1$ and the covariance of $\ln c_1$ and $\ln y_1$ do not depend on g. In fact,

[9] Here, we focus on a short-run effect where the risk-free interest rate and the initial distribution of income and wealth are fixed.

for any value of g, we have $Var(\ln c_1) = Var(\ln y_1)$ and $Cov(\ln c_1, \ln y_1) = Var(\ln y_1)$. Therefore, the correlation of log income and consumption is 1. Note that because of this equality, changes in variance of log income is fully translated to changes in variance of log consumption. When variance of log income increase due to changes in skill biased technology A^s_t, the dynamics is reflected in variance of log consumption as shown in Figure 11.

Case 2: Next, we suppose that the initial asset holdings a_1 vary across households. For simplicity, we further suppose that a_1 takes on only two values, $a_1 \in \{a_L, a_H\}$ with $a_L = 0$ and $a_H > 0$. Let π denote the fraction of households with $a_1 = a_H$. Furthermore, suppose that $y_1 = \bar{y} = 1$ for all households. Consider the following two cases with different growth rates of g_L and g_H.

(i) $\Gamma < g_H$. For $a_1 = a_L = 0$, the borrowing constraint binds, because $(\Gamma - g_H)y_1 < 0$. Suppose that a_H is large enough so that $\Gamma(y_1 + (1+r)a_H) > g_H\bar{y}$. Then, for $a_1 = a_H$, the borrowing constraint does not bind for households with $a_1 = a_H$. Note that with the non-degenerate wealth distribution, unlike Case 1, households with binding borrowing constraints and those without can coexist.

(ii) $\Gamma \geq g_L$. In this case, for all a_1, $\Gamma x_1 \geq g_L\bar{y}$. Thus, for all households, the borrowing constraint does not bind.

Let $c_L(g)$ and $c_H(g)$ denote, given the growth rate of g, consumption when $a_1 = a_L$ and that when $a_1 = a_H$, respectively. First, let us examine the level difference between c_H and c_L in the above two cases. For $g = g_H$,

$$c_H(g_H) - c_L(g_H) = \frac{1+r}{1+r+\Gamma}(x_H - x_L) + \underbrace{\frac{g_H - \Gamma}{1+r+\Gamma}}_{>0}\bar{y}.$$

For $g = g_L$,

$$c_H(g_L) - c_L(g_L) = \frac{1+r}{1+r+\Gamma}(x_H - x_L).$$

Thus, $c_H(g_H) - c_L(g_H) > c_H(g_L) - c_L(g_L)$.[10] Next, let us examine the variance of log consumption. Let $Var(\ln c_1)|_g$ denote the variance of log consumption when the growth rate is g. We can show that

$$\begin{aligned} Var(\ln c_1)|_{g_L} - Var(\ln c_1)|_{g_H} &\gtreqless 0 \\ \Leftrightarrow \underbrace{\frac{\Gamma - g_H}{1+r+\Gamma}}_{<0}\bar{y} + \underbrace{\left(\frac{(1+r)^2}{1+r+g_L} - \frac{(1+r)^2}{1+r+\Gamma}\right)}_{>0} a_H &\gtreqless 0 \end{aligned}$$

[10]The same result holds in Case 1.

Recall that $(c_H(g_L) - c_L(g_L)) - (c_H(g_H) - c_L(g_H)) = \frac{\Gamma - g_H}{1+r+\Gamma}$. Thus, the first term represents the effect of the growth slowdown on the dispersion in the level consumption. On the other hand, the second term represents a level effect, as g_L governs the level of $c_L(g_L)$ and $c_H(g_L)$. When the first term dominates, the variance of log consumption decreases as the aggregate growth rate declines.[11]

This examples show that changes in the aggregate growth rate can affect the cross-sectional distribution of consumption through changes in the fraction of households facing binding borrowing constraints. The higher the aggregate growth rate, the more households tend to face binding borrowing constraints.

Based on the arguments above, we discuss how growth rate slowdown of aggregate TFP and changes in skill biased technology affect cross-sectional moments. For simplicity, we consider a case where $a_1 = 0$ for all households and that there are households with high expected growth and low expected growth. Then consumption choice of the two households will be expressed as

$$\begin{aligned} c_j^s &= \gamma y_j^s \text{ where } \gamma \equiv \frac{1+r+g_H}{1+r+\Gamma} \\ c_j^u &= \alpha y_j^u \text{ where } \alpha \equiv \frac{1+r+g_L}{1+r+\Gamma}. \end{aligned}$$

We further assume that the population of the two types of households are expressed as Φ^s and Φ^u respectively and mean income in each household group is expressed by y^s and y^u. Then the covariance of log income and log consumption across all households is given by

$$\Phi^s \sum \left(\log c_j^s - \log c\right) \left(\log y_j^s - \log y\right) + (1 - \Phi^s) \sum \left(\log c_j^u - \log c\right) \left(\log y_j^u - \log y\right), \tag{13}$$

where

$$\begin{aligned} \log c &\equiv \Phi^s \log y^s + (1 - \Phi^s) \log y^u + \Phi^s \log \gamma + (1 - \Phi^s) \log \alpha \\ \log y &\equiv \Phi^s \log y^s + (1 - \Phi^s) \log y^u. \end{aligned}$$

This equation reduces to

$$\begin{aligned} &\Phi^s \sum \left(\log y_j^s - \log y + (1 - \Phi^s) \log \gamma - (1 - \Phi^s) \log \alpha\right) \left(\log y_j^s - \log y\right) \\ &+ (1 - \Phi^s) \sum \left(\log y_j^u - \log y - \Phi^s \log \gamma + \Phi^s \log \alpha\right) \left(\log y_j^u - \log y\right) \end{aligned}$$

Considering that higher growth rate of skill biased technology increases γ, its impact on covariance is obtained by taking the first derivative of the equation above with respect

[11] Note that if the borrowing constraint does not bind with the high (and low) growth rate, the first term disappears and the variance of log consumption *increases* with growth rates.

to γ. Because on average skilled households receive higher labor income than unskilled households, which implies $\sum\left(\log y_j^s - \log y\right) > \sum\left(\log y_j^u - \log y\right)$, the increase in γ implies a higher covariance as shown in Figure 15. In order to discuss effects of aggregate technology slowdown, we assume that γ is unity and consider a case that impact of decrease in Φ^s in the following equation.

$$\Phi^s \sum \left(\log y_j^s - \log y - (1-\Phi^s)\log\alpha\right)\left(\log y_j^s - \log y\right)$$
$$+ (1-\Phi^s)\sum\left(\log y_j^u - \log y + \Phi^s \log\alpha\right)\left(\log y_j^u - \log y\right)$$

The effect is positive when Φ^s is sufficiently small as is the case in our model.

6 Conclusion

Japan's economy has substantially changed from the early 1990s. That is, growth rates of the aggregate macroeconomic variables have declined and the declines have persisted more than two decades. In this paper, we study how the second moments across households, including income and consumption inequalities and income-consumption correlation, have responded to the changes in the aggregate economic circumstances.

To this end, we first conduct the econometric analysis and study how time series properties of the inequalities have statistically changed before and during the lost decades. We construct monthly series of inequalities from 1981 to 2008 using micro data set on Japanese households, the Family Income and Expenditure Survey (FIES). We conduct structural break tests developed by Bai and Perron (1998) to these series and check the timing and size of changes in the inequality series. We find that the lost decades has come together with changes in the way that the time series of inequality evolve. That is, growth rates of income and consumption inequality have slowed down and correlation between income and consumption across households has declined during the lost decades. The growth rate declines in inequalities and lower correlation have never reverted back to the growth rates and the level of the 1980s even in the current years.

Next, we ask theoretically if these observed changes in the inequalities and the changes in the macroeconomic activities are accounted for by the common economic factors. To do this, we construct a dynamic general equilibrium model with heterogeneous households with different degree of skills and idiosyncratic income shocks. We study if the growth rate slowdown of the aggregate TFP, skill biased technology, or both may account for changes in income and consumption inequalities and income-consumption correlation as well as the aggregate output growth. Our theoretical analysis shows that a growth rate decline in both of the technologies are needed to bring the model close to the data.

In the current paper, we focus on documenting changes in cross-sectional moments across Japaneses households and theoretically studying why they have occurred. Though it is not discussed in the current study, our findings have important policy implications. For instance, the slowdown of the inequality growth may have contributed to mitigating the social welfare loss due to the slowdown of the aggregate output growth during the lost decades.[12] In addition, the decline in the correlation between income and consumption may have influenced the transmission mechanism of macroeconomic stabilization policy, such as monetary policy and government expenditure policy. Extending our framework in that direction remains a future goal of our continuing research.

References

Acemoglu, D. (2002). Technical change, inequality, and the labor market. *Journal of Economic Literature 40*(1), 7–72.

Bai, J. and P. Perron (1998). Estimating and testing linear models with multiple structural changes. *Econometrica 66*(1), 47–78.

Braun, R. A., D. Ikeda, and D. Joines (2009). The saving rate in Japan: Why it has fallen and why it will remain low. *International Economics Review 50*(1), 291–321.

Conesa, J. C. and D. Krueger (1999). Social security with heterogeneous agents. *Review of Economic Dynamics 2*(4), 757–795.

Hayashi, F. and E. C. Prescott (2002). The 1990s in Japan: A lost decade. *Review of Economic Dyamics 5*(1), 206–235.

Heathcote, J., K. Storesletten, and G. L. Violante (2010). The macroeconomic implications of rising wage inequality in the United States. *Journal of Political Economy 118*(4), 681–672.

Heathcote, J., K. Storesletten, and G. L. Violante (2012). From wages to welfare: Decomposing gains and losses from rising inequality. In D. Acemoglu, M. Arellano, and E. Dekel (Eds.), *Advances in Economics and Econometrics: Theory & Applications, Tenth World Congress of the Econometric Society*, pp. 235–282. Cambridge: Cambridge University Press.

Heckman, J. J., L. Lochner, and C. Taber (1998). Explaining rising wage inequality: Explorations with a dynamic general equilibrium model of labor earnings with heterogeneous agents. *Review of Economic Dynamics 1*(1), 1–58.

İmrohoroğlu, S. and N. Sudo (2011). Will a growth miracle reduce debt in Japan. IMES Discussion Paper Series, 11-E-01.

[12] See for example Heathcote et al. (2012) where welfare implications of rising economic inequality in the U.S. is analyzed.

Kopecky, K. and R. Suen (2010). Finite state markov-chain approximations to highly persistent processes. *Review of Economic Dynamics 13*, 701–714.

Krueger, D., F. Perri, L. Pistaferri, and G. L. Violante (2010). Cross-sectional facts for macroeconomists. *Review of Economic Dynamics 13*(1), 1–14.

Lise, J., N. Sudo, M. Suzuki, K. Yamada, and T. Yamada (2014). Wage, income and consumption inequality in Japan, 1981-2008: from boom to lost decades. Forthcoming, Review of Economic Dynamics.

Meyer, B. D. and J. X. Sullivan (2013). Consumption and income inequality and the great recession. *American Economic Review: Papers & Proceedings 103*(3), 178–183.

Muto, I., N. Sudo, and S. Yoneyama (2013). Productivity slowdown in Japan's lost decades: How much of it is attributed to financial factors? Dynare Working Paper Series, No. 28.

Rouwenhorst, K. G. (1995). Asset pricing implications of equilibrium business cycle models. In T. Cooley (Ed.), *Frontiers of Business Cycle Researc*, pp. 294–330. New Jersey: Princeton University Press.

Storesletten, K., C. I. Telmer, and A. Yaron (2004). Cyclical dynamics in idiosyncratic labor-market risk. *Journal of Political Economy 112*(3), 695–717.

Yamada, T. (2012). Income risk, macroeconomic and demographic change and economic inequality in Japan. *Journal of Economic Dynamics and Control 36*, 63–84.

A Tables

Table 1: Period and Size of Break in Mean Income (y_D) Growth by Characteristics

	Break Period		Break Size (YoY Growth Rate)		
	Break I	Break II	Average Growth	Break I	Break II
			Income Quintile		
0-20%	1998.11	2004.01	0.013764	-0.03078	0.02364
20-40%	1998.11	NA	0.014942	-0.01822	NA
40-60%	1996.09	NA	0.016629	-0.01755	NA
60-80%	1993.08	NA	0.018337	-0.01928	NA
80-100%	1992.01	NA	0.020773	-0.02117	NA
			Occupation		
Regular Labourers	1997.02	2004.01	0.016479	-0.03321	0.01954
Temporary Worker	NA	NA	-0.008304	NA	NA
Private Office Workers	1992.12	NA	0.020025	-0.02075	NA
Officials	2001.04	NA	0.014046	-0.02092	NA
			Industry		
Mining	NA	NA	-0.004828	NA	NA
Construction	1987.02	1993.02	0.006478	0.03496	-0.04834
Manufacturing	1998.11	2003.09	0.018161	-0.03560	0.02391
Electricity	NA	NA	0.008807	NA	NA
Transportation	1997.08	NA	0.016723	-0.02071	NA
Wholesale and Resale	1992012	NA	0.020473	-0.02382	NA
Financial Sector	NA	NA	0.006870	NA	NA
Real Estate	NA	NA	0.005945	NA	NA
Service	1998.06	2004.01	0.011985	-0.03254	0.02117
Public	1999.06	NA	0.018161	-0.02511	NA
			Age		
25-29	1992.11	NA	0.026653	-0.03501	NA
30-39	1996.02	NA	0.019430	-0.02395	NA
40-49	1992.06	NA	0.018501	-0.01846	NA
50-59	1999.02	2003.12	0.010134	-0.03375	0.03202

Table 2: Period and Size of Break in Mean Consumption (c_{ND}) Growth by Characteristics

	Break Period		Break Size (YoY Growth Rate)		
	Break I	Break II	Average Growth	Break I	Break II
			Income Quintile		
0-20%	1992.06	NA	0.011827	-0.01576	NA
20-40%	1993.01	NA	0.011609	-0.01632	NA
40-60%	1991.02	NA	0.014911	-0.01665	NA
60-80%	1993.06	NA	0.012930	-0.01644	NA
80-100%	NA	NA	0.002869	NA	NA
			Occupation		
Regular Labourers	1991.04	NA	0.013128	-0.01792	NA
Temporary Worker	NA	NA	-0.003117	NA	NA
Private Office Workers	1987.12	1992.04	0.004043	0.01768	-0.02425
Officials	NA	NA	0.002686	NA	NA
			Industry		
Mining	NA	NA	-0.005176	NA	NA
Construction	1987.03	1991.04	0.002263	0.03486	-0.04128
Manufacturing	1992.04	NA	0.017000	-0.02043	NA
Electricity	NA	NA	0.001978	NA	NA
Transportation	NA	NA	0.002975	NA	NA
Wholesale and Resale	1992.12	NA	0.014507	-0.01883	NA
Financial Sector	NA	NA	0.001618	NA	NA
Real Estate	NA	NA	-0.003677	NA	NA
Service	NA	NA	-0.000190	NA	NA
Public	NA	NA	0.003495	NA	NA
			Age		
25-29	NA	NA	-0.001252	NA	NA
30-39	1994.08	NA	0.009184	-0.01373	NA
40-49	1991.02	NA	0.012980	-0.01640	NA
50-59	1992.12	NA	0.009767	-0.01430	NA

Table 3: Calibration

Parameter	Value	Source/Target
β	0.98	$K/Y \approx 2 \sim 2.5$
γ	2.0	IES=0.5
g_t	{1.84%,0.16%}	Muto, et al. (2013)
α	0.377	İmrohoroğlu and Sudo (2011)
δ	0.08	İmrohoroğlu and Sudo (2011)
λ	0.97	Yamada (2012)
σ_ψ^2	0.01	Lise, et al. (2014)
σ_ξ^2	0.03	Lise, et al. (2014)
ρ	0.29	Heathcote, et al. (2010)
A^s/A^u	0.3233	Acemoglu (2002)
j^{ret}	45	Retire at 65
J	81	Live at most 100
$\{\kappa_j^e\}$	–	BSWS
$\{s_j\}$	–	IPSR (2012)
n	0.0	IPSR (2012)
τ^y	10.0%	
τ^k	39.8%	İmrohoroğlu and Sudo (2011)
τ^{ss}	13.58%	Value in 2004

B Figures

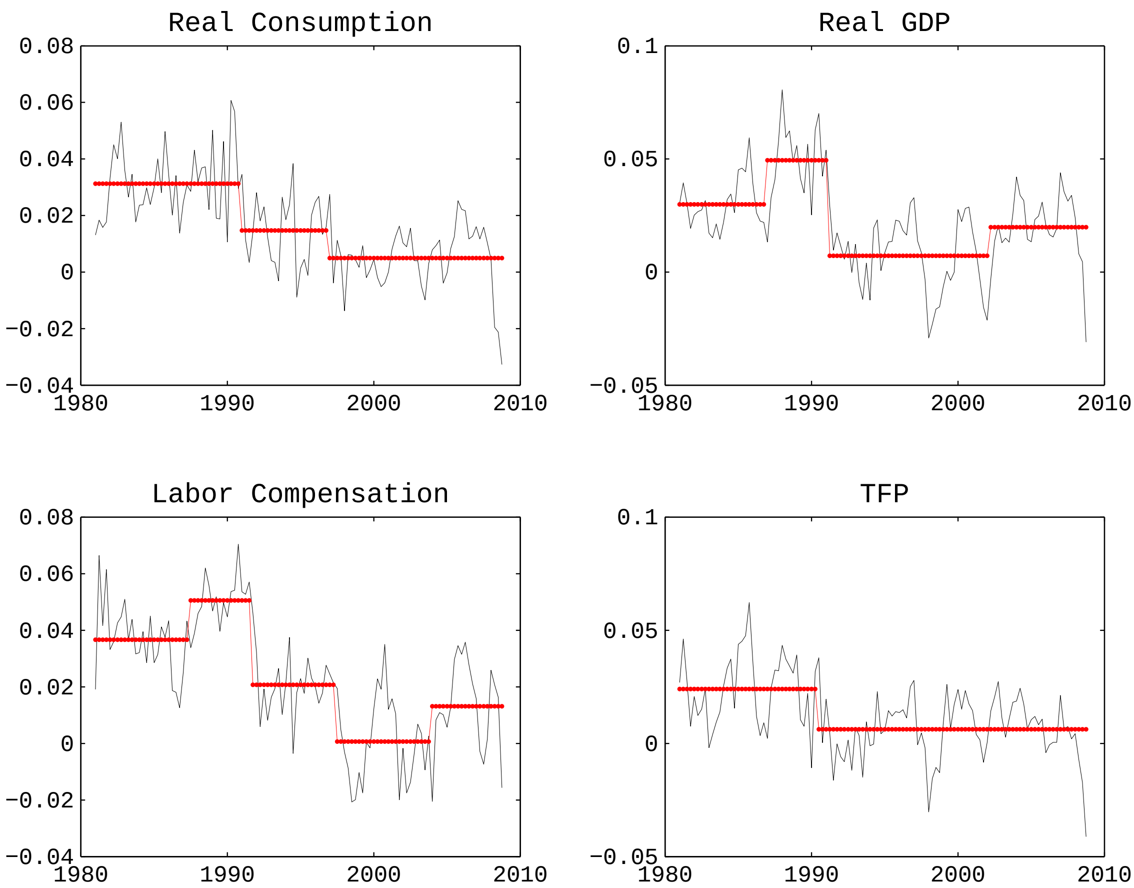


Figure 1: Time Path of Macroeconomic Variables during the Lost Decades

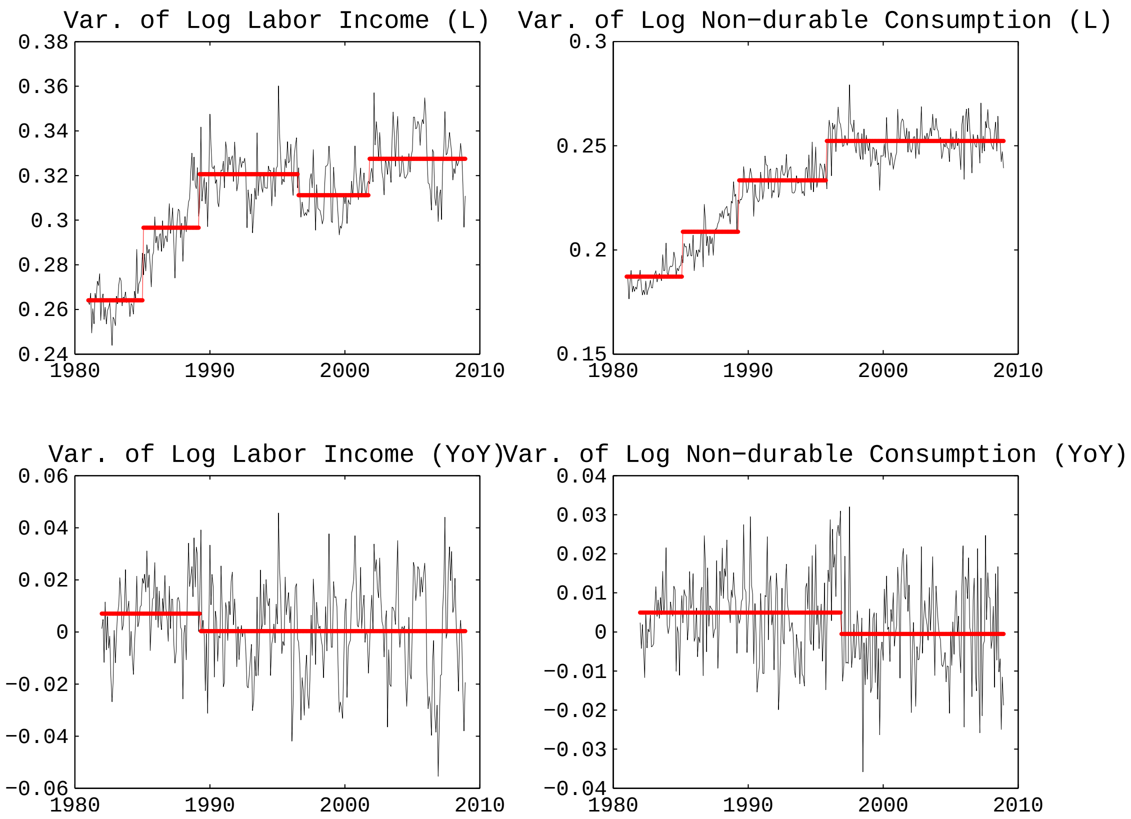


Figure 2: Variance of Income and Consumption across Households

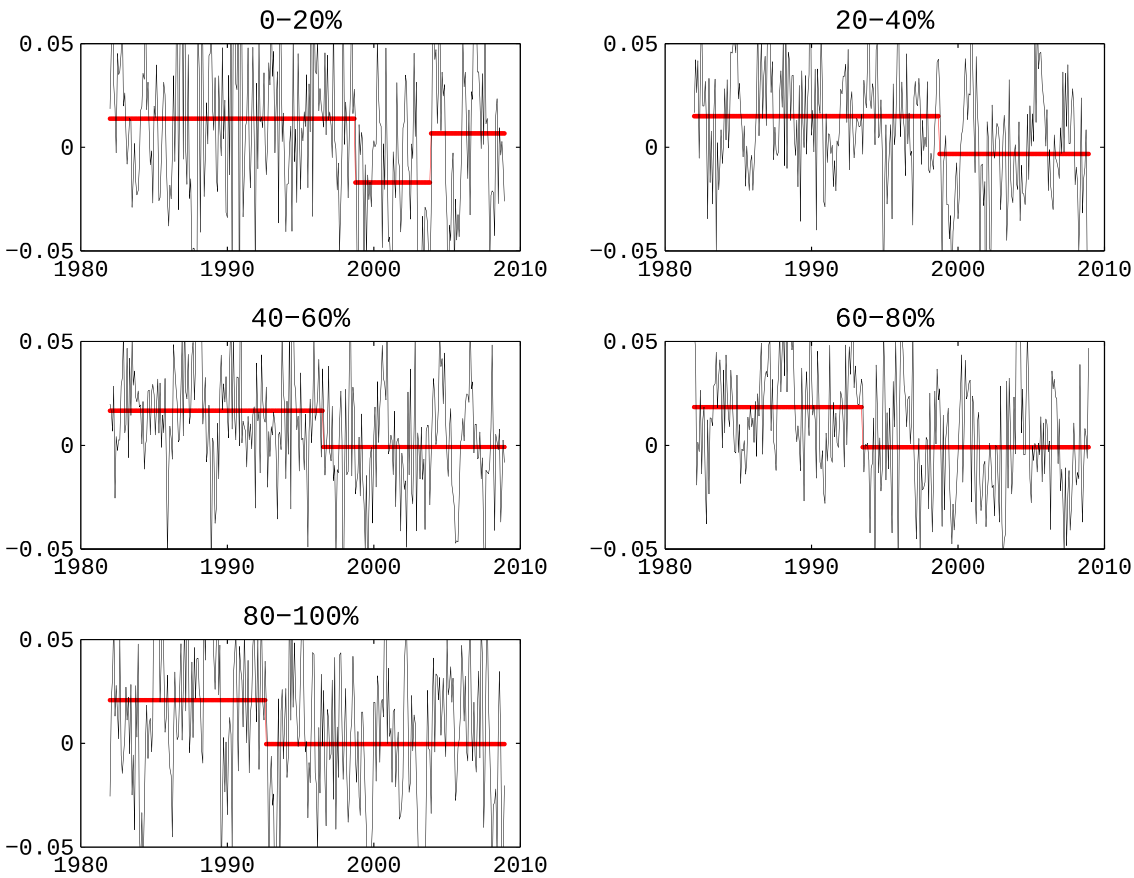


Figure 3: Income Growth of Households with Different Income Quintiles

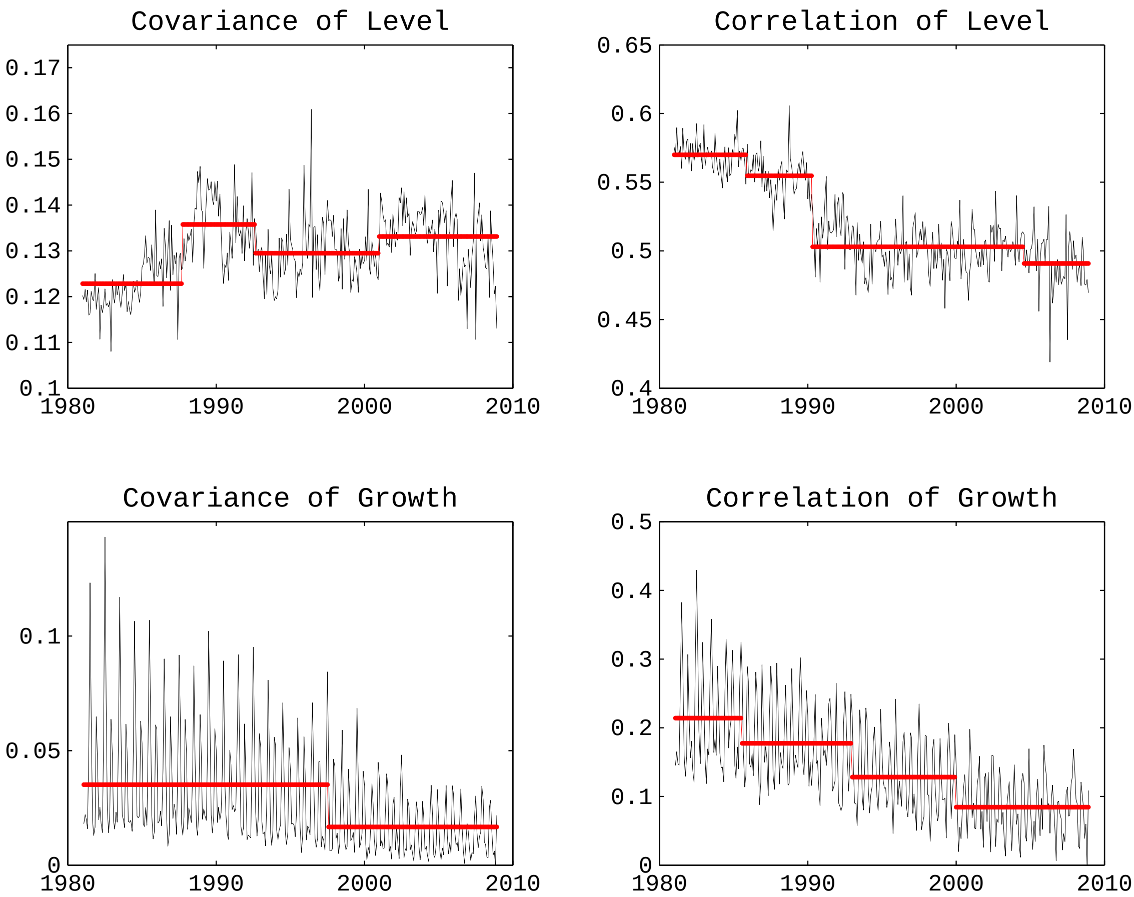


Figure 4: Transmission from Income Growth to Consumption Growth

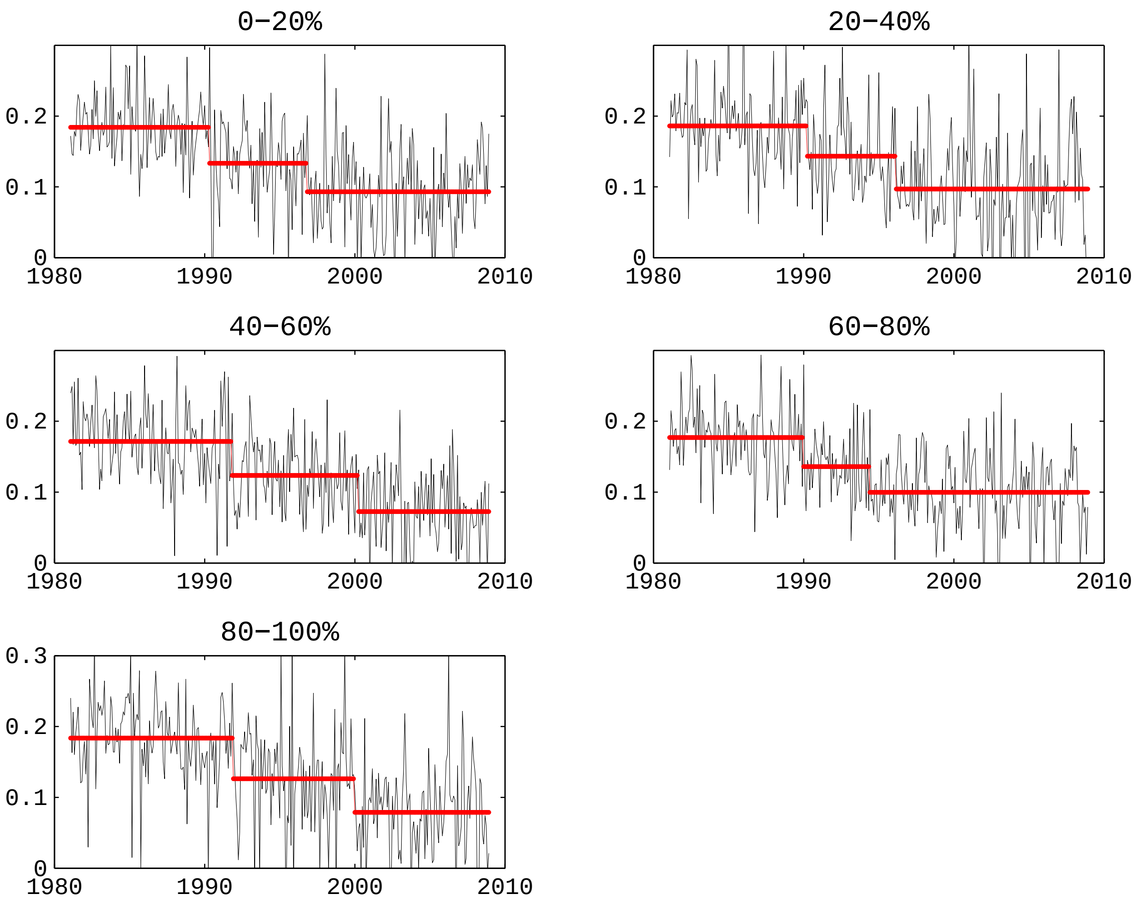


Figure 5: Income-Consumption Growth Covariance of Households with Different Income Quintiles

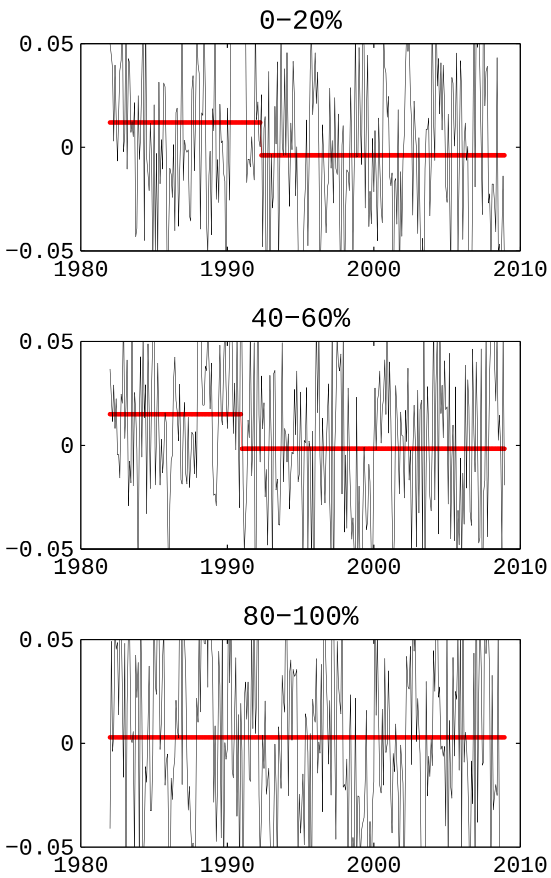
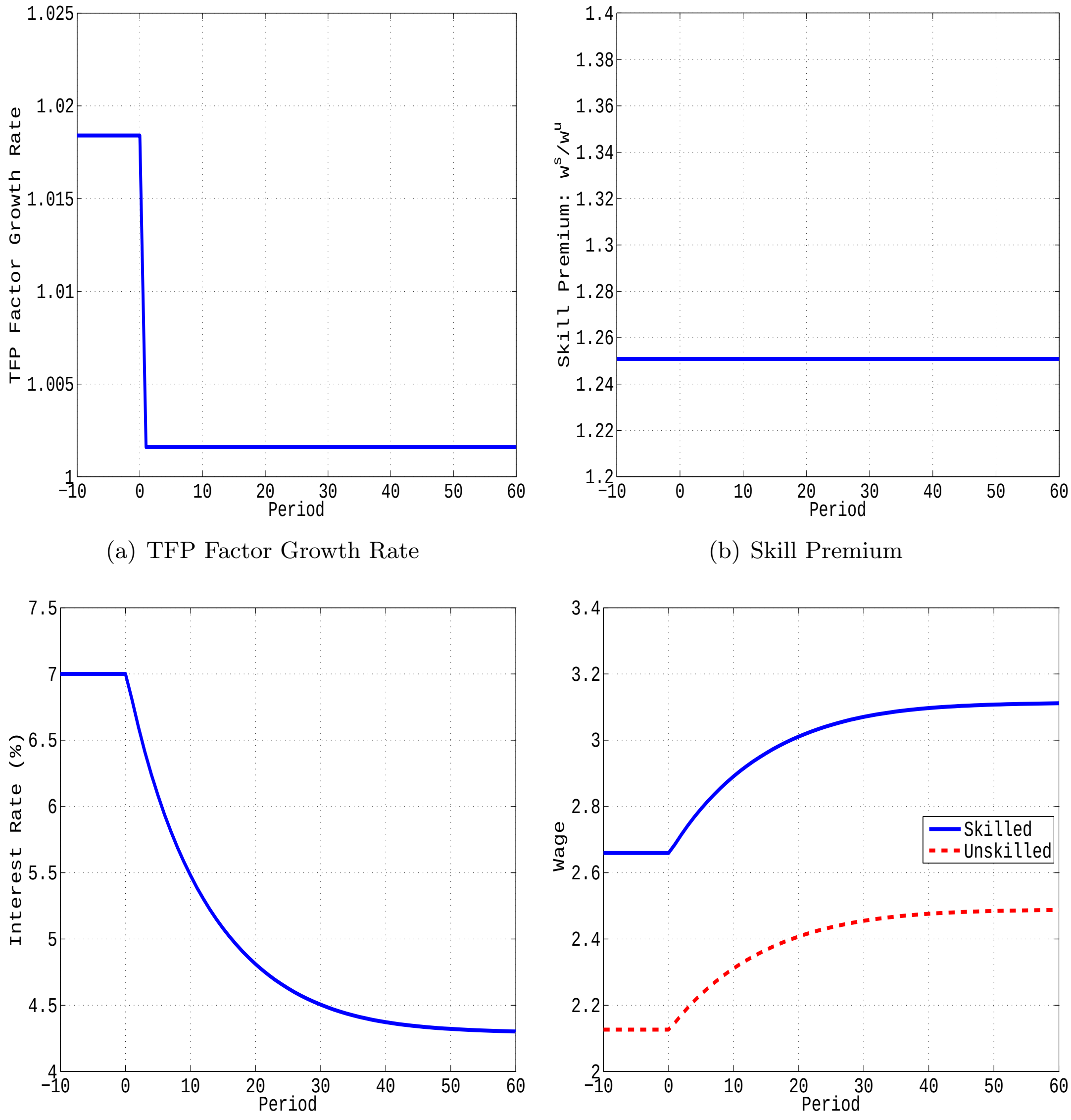


Figure 6: Consumption Growth of Households with Different Income Quintiles



(a) TFP Factor Growth Rate

(b) Skill Premium

(c) After-tax Rate of Return

(d) Wage

Figure 7: Equilibrium Paths with One-time TFP Shock

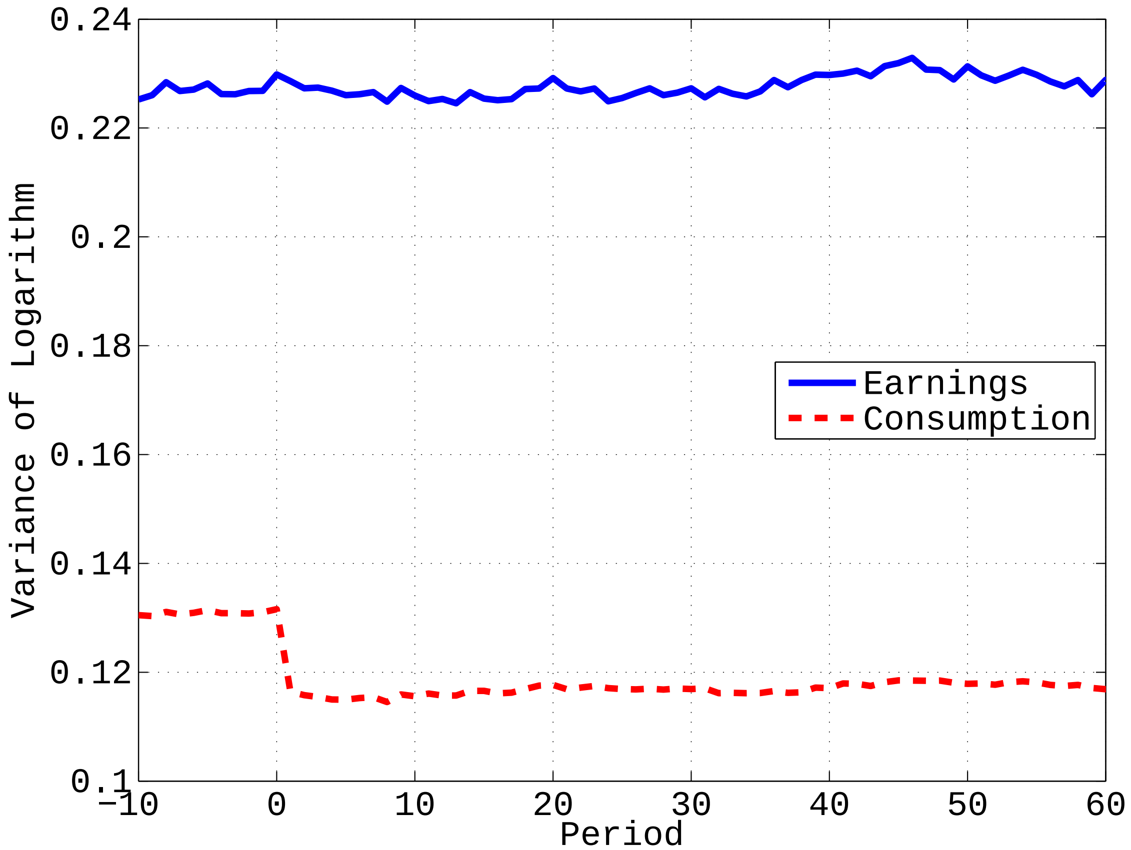
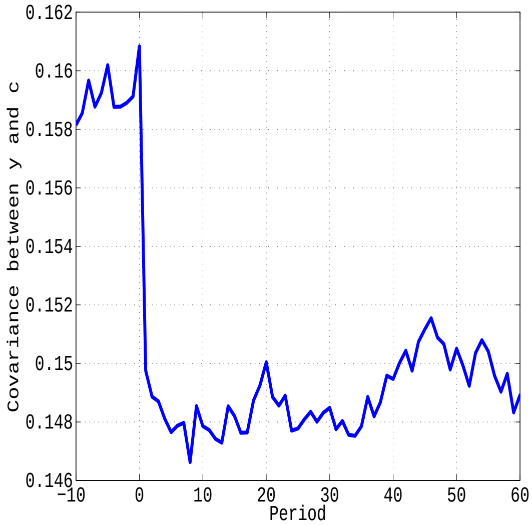
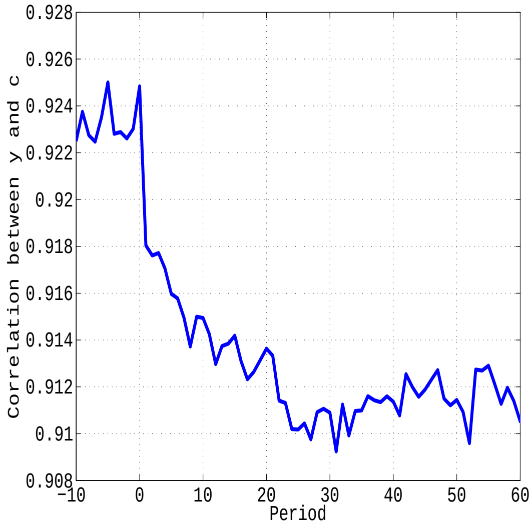


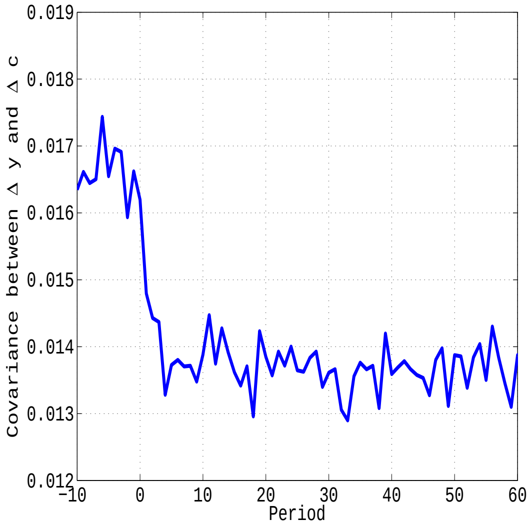
Figure 8: Variance of Logarithm of Earnings and Consumption with One-time TFP Shock



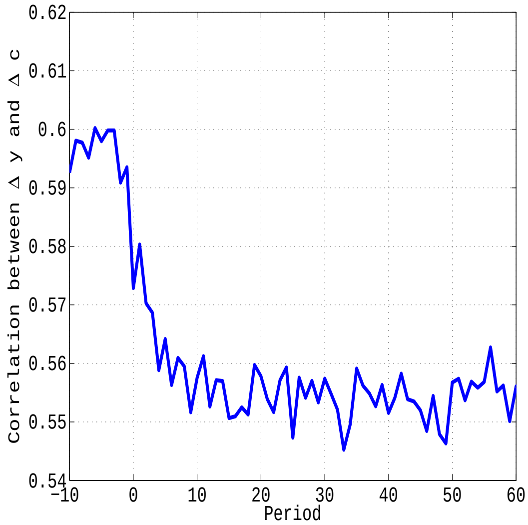
(a) Covariance between y and c



(b) Correlation between y and c

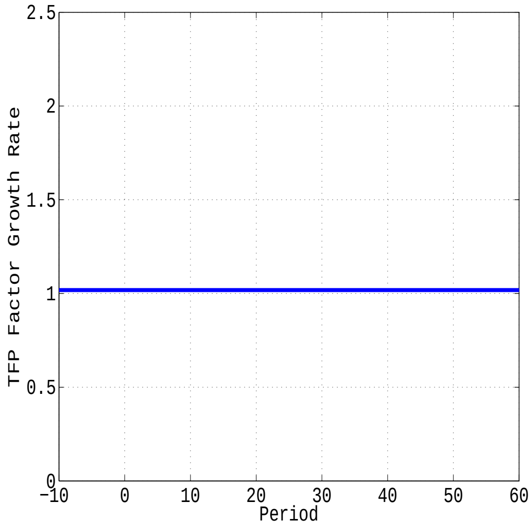


(c) Covariance between Δy and Δc

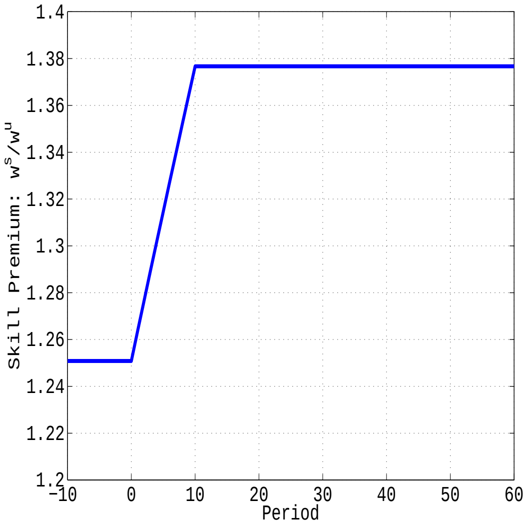


(d) Correlation between Δy and Δc

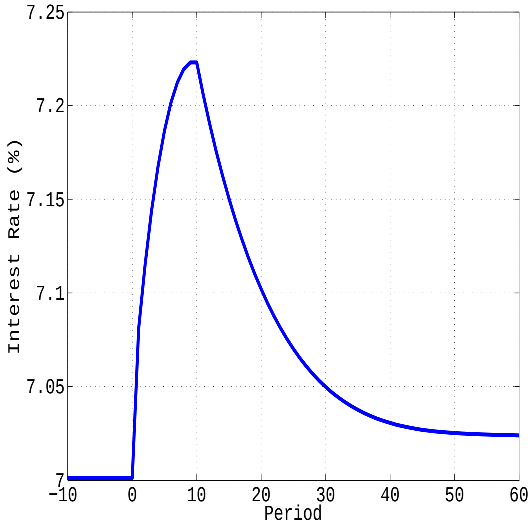
Figure 9: Covariances and Correlations with One-time TFP Shock



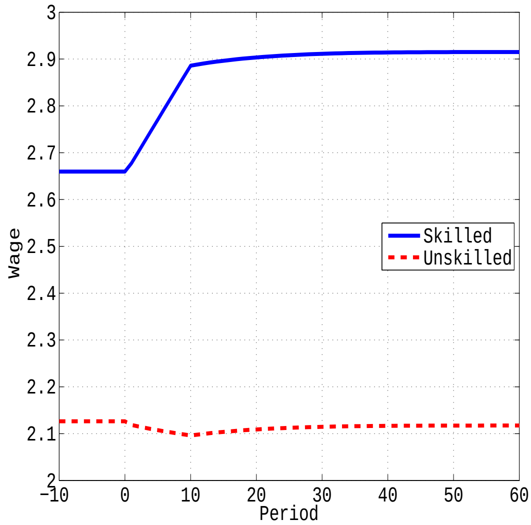
(a) TFP Factor Growth Rate



(b) Skill Premium



(c) After-tax Rate of Return



(d) Wage

Figure 10: Equilibrium Paths with One-time Skill Shock

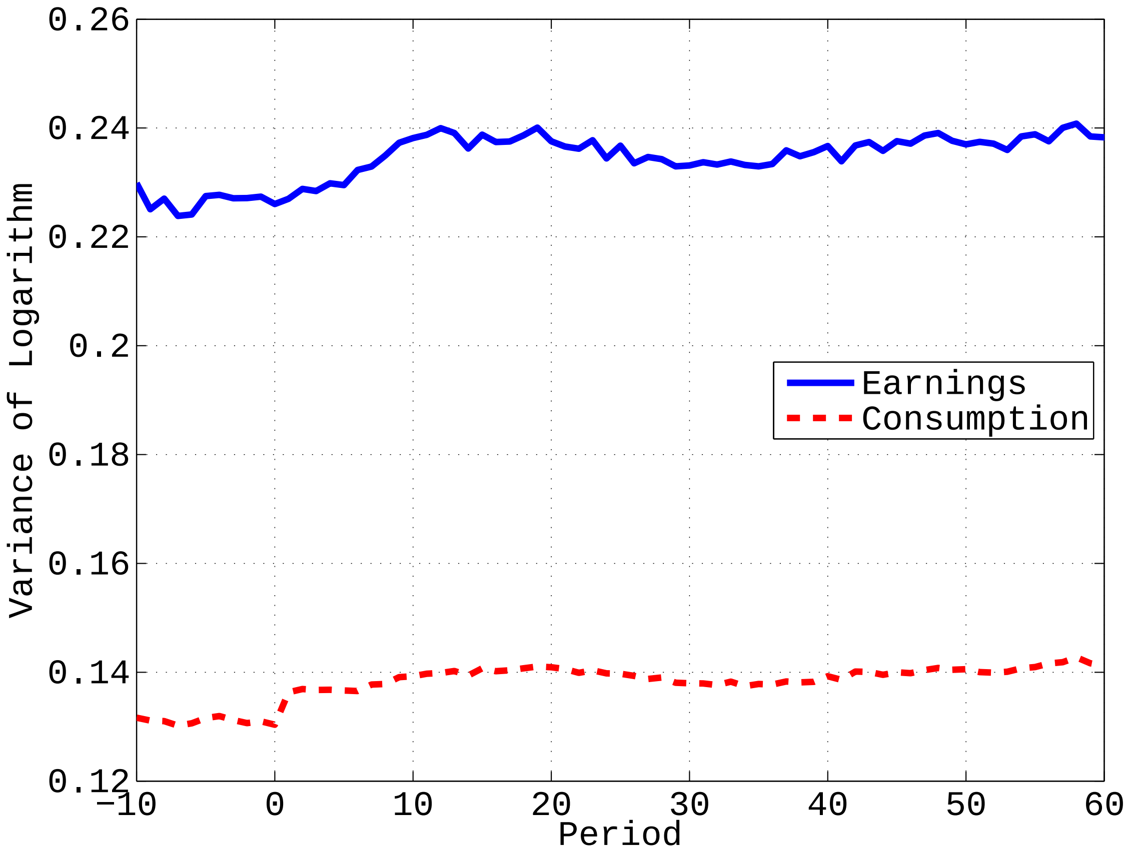
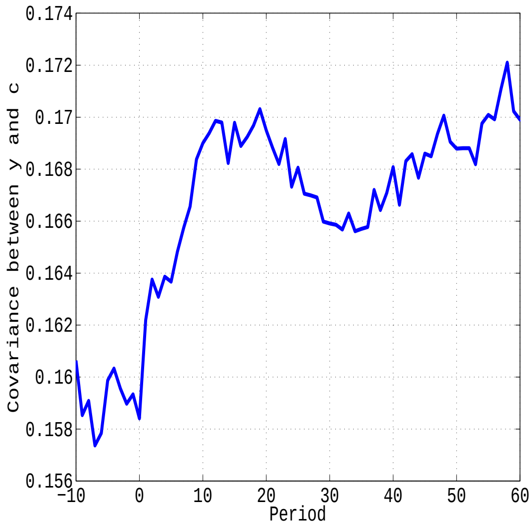
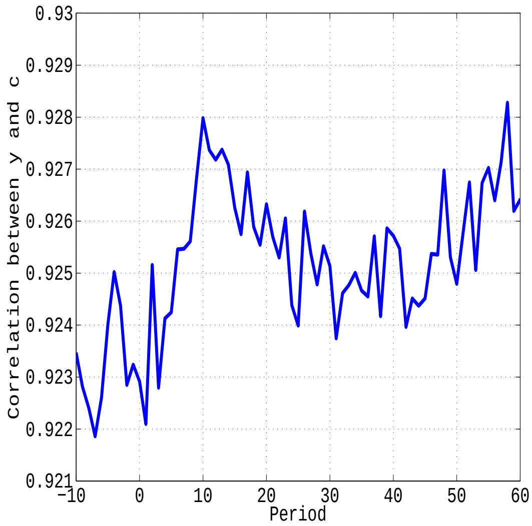


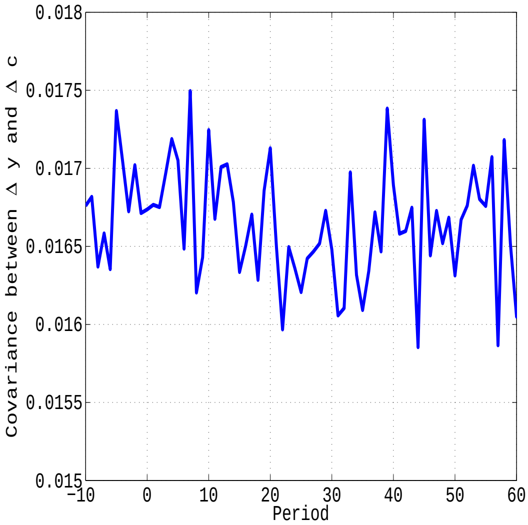
Figure 11: Variance of Logarithm of Earnings and Consumption with One-time Skill Shock



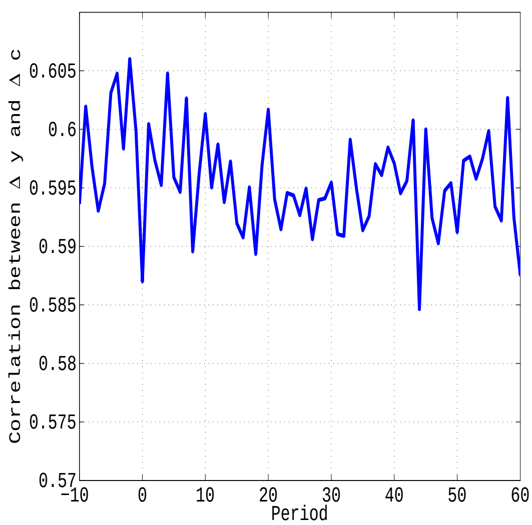
(a) Covariance between y and c



(b) Correlation between y and c

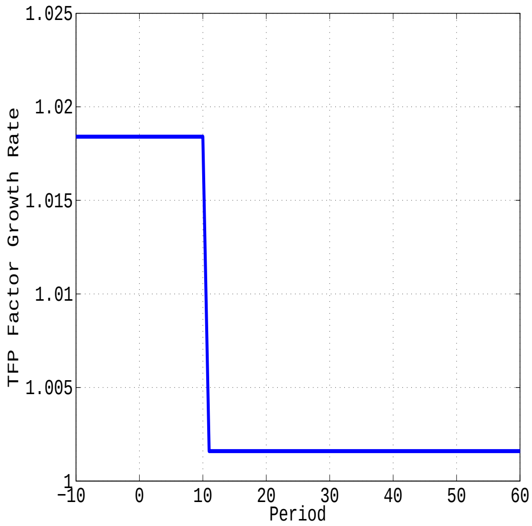


(c) Covariance between Δy and Δc

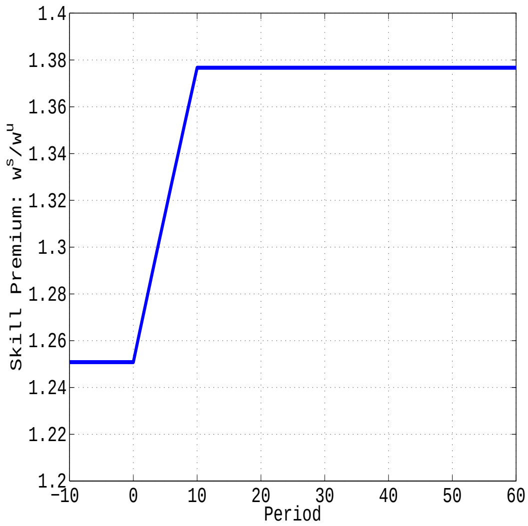


(d) Correlation between Δy and Δc

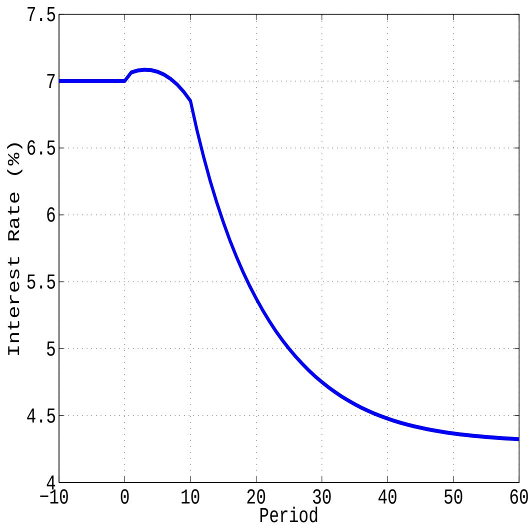
Figure 12: Covariances and Correlations with One-time Skill Shock



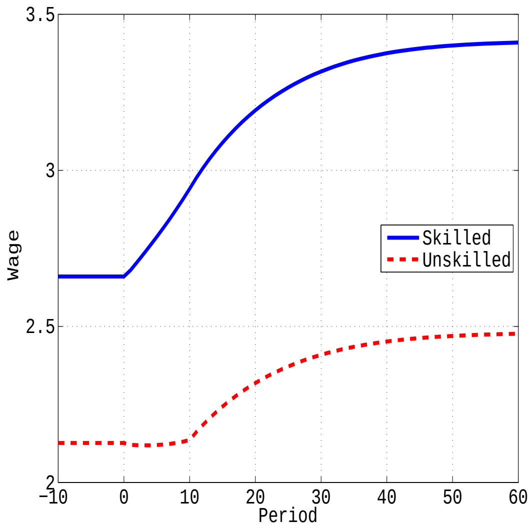
(a) TFP Factor Growth Rate



(b) Skill Premium



(c) After-tax Rate of Return



(d) Wage

Figure 13: Equilibrium Paths with One-time TFP and Skill Shock

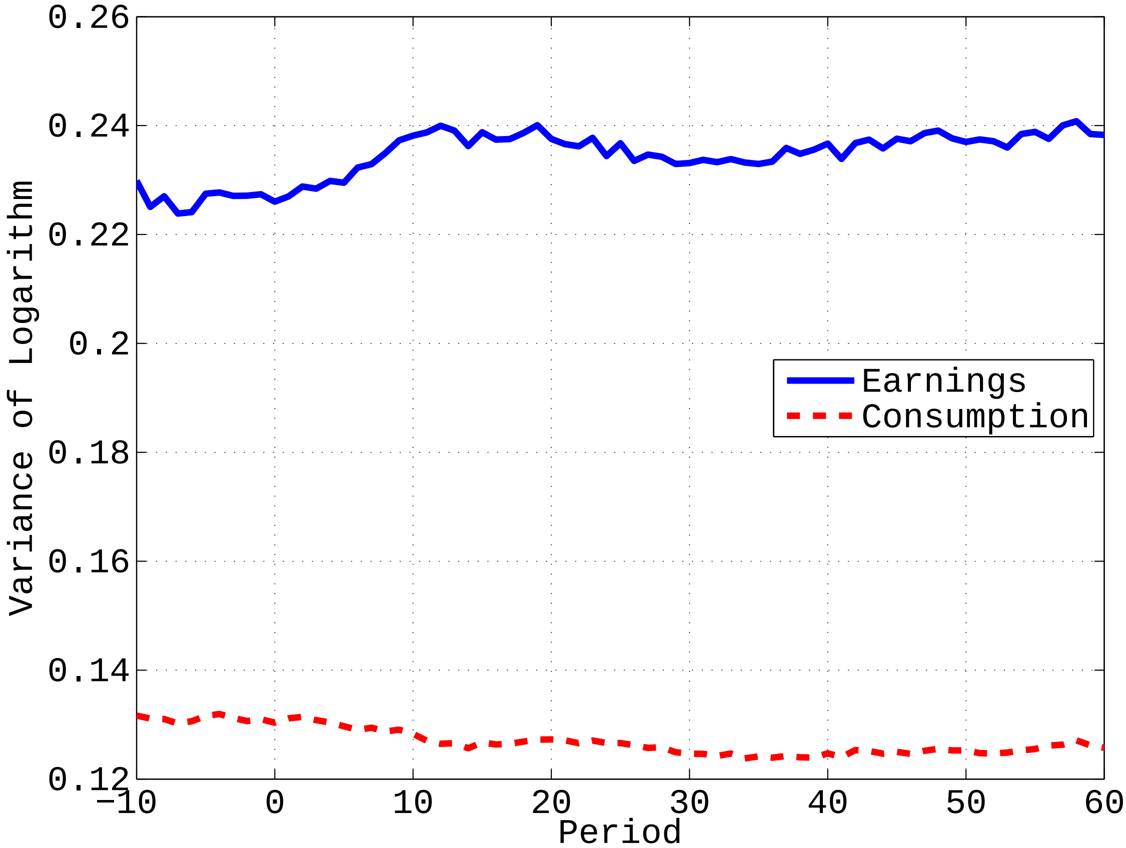
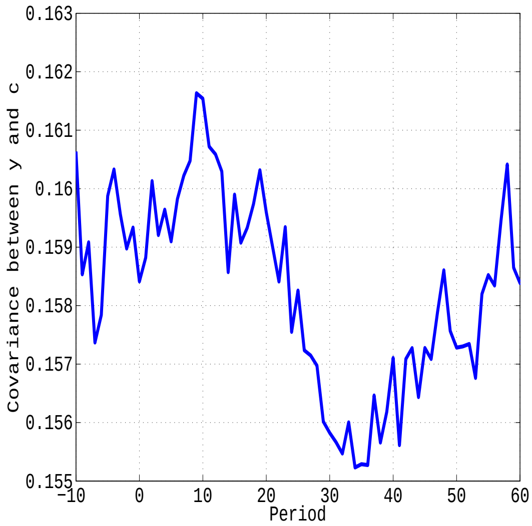
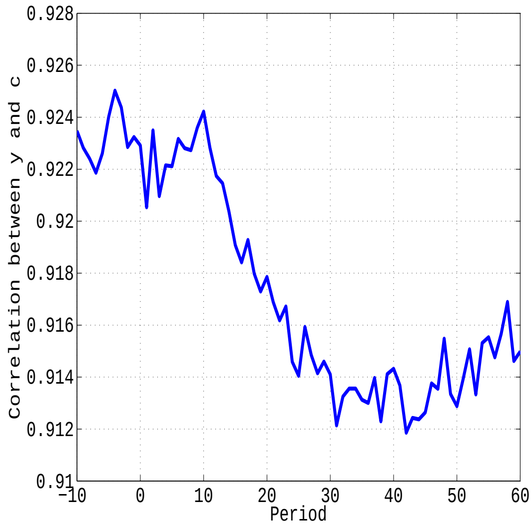


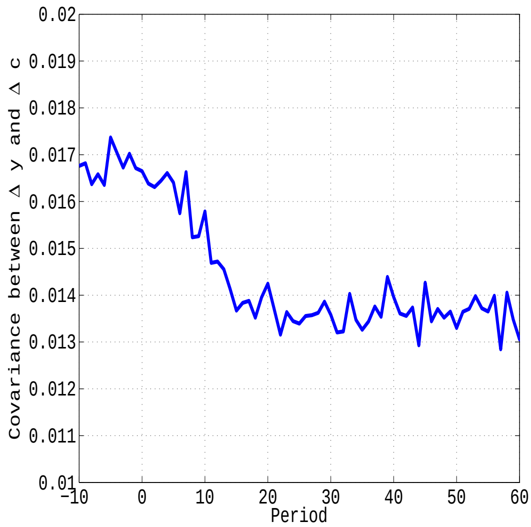
Figure 14: Variance of Logarithm of Earnings and Consumption with One-time TFP and Skill Shock



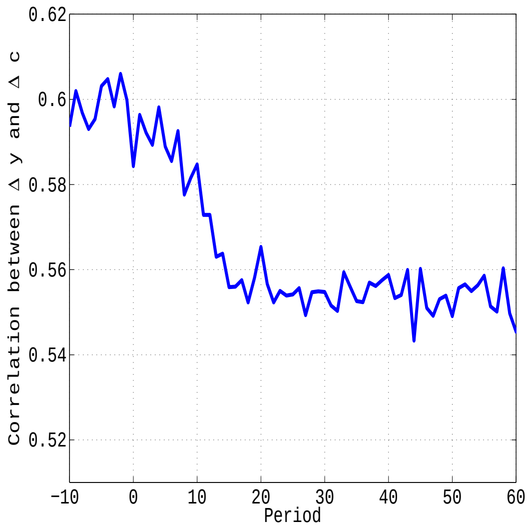
(a) Covariance between y and c



(b) Correlation between y and c



(c) Covariance between Δy and Δc



(d) Correlation between Δy and Δc

Figure 15: Covariances and Correlations with One-time TFP and Skill Shock