The Effects of Wage Volatility on Growth

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Abstract

This paper shows that wage volatility has significant effects on a country's rate of economic growth. Our theoretical framework suggests two distinct channels in which wage volatility affects growth: a positive direct way and a negative indirect way. The direct effect stems from precautionary savings, whereas the indirect effect works through the mediating role of government size. In the empirical part, we use a 3SLS approach to analyze a panel of 20 high-income OECD countries and find strong evidence for the existence of both effects. These results carry general and specific implications. In general, one needs to carefully consider indirect effects operating through the size of government when analyzing the effect of volatility on growth. Specific to wage volatility, our results suggest that a one standard deviation increase of volatility causes a 0.12 to 0.14 percent net *increase* in GDP per capita.

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1 Introduction

Why do some countries grow faster than others? Over the last decades, it became clear that one standardized response may not suffice to answer this question. An economy requires a combination of economic and political factors, plus for different countries and regions a distinct set of conditions may have to hold in order to foster growth.[1] In this context, using panel data versus cross-sectional data is of eminent importance in empirical work since it allows to control for potentially unobserved time invariant differences between countries (see Durlauf et al., 2008, for instance). Correspondingly, the benchmark list of globally accepted growth determinants is rather short. According to Mirestean and Tsangarides (2009), this list consists of debt, openness, inflation, initial income, investment, life expectancy, and population growth.

In light of the 2008 global financial crisis, it might be time to revisit another phenomenon in the growth context: volatility in key macroeconomic variables. This paper focuses on the volatility of wages with its direct and (previously masked) indirect effects on growth. Our contribution to the literature is twofold: we (1) show that wage volatility does have significant effects on growth, which to our knowledge has not been pointed out before, and (2) suggest an explanation why growth analyses of various other sorts of volatility could not point to a decisive answer.

Previous works on several types of volatility and their effects on growth produced heterogeneous results. In a comprehensive look at volatility in small open economies, Turnovsky and Chattopadhyay (2003) conclude that both monetary and terms-of-trade volatility lower growth. Similarly, Ramey and Ramey (1995) find negative growth effects from volatile growth rates itself, being one of the first papers to conclusively relate the business cycle to growth rates. Posch and Wälde (2011) on the other hand argue that no causality at all runs from volatility to growth. Finally, Devereux and Smith (1994) suggest that international risk sharing (i.e. lower volatility) in terms of portfolio choices reduces precautionary savings, which in turn lowers growth. This

[1] For a discussion of various possible sources of growth see, for instance, Barro and Lee (1994), Alesina et al. (1996), Barro (1996), Barro and Sala-i Martin (1997), or Frankel and Romer (1999) among many others. For good summaries, please refer to Temple (1999), Durlauf and Quah (1999) or Sala-i Martin et al. (2004). Brock and Durlauf (2001) provide additional reasons for the heterogeneity of growth determinants and provide potential avenues for solutions. Other works, such as Henderson et al. (2012) are beginning to point out the importance of non-linearities among growth determinants.

short selection of papers shows that arguments for both negative and positive effects of different kinds of volatility on growth have been suggested.

Another stream of the volatility literature deals with its relationship to government size. Rodrik (1998) concludes that external risk encourages people to call for a stronger public safety net and/or seek a (safer) job with the government. Hence, volatility in private sector wages could be a determinant of the size of the public sector.[2] Finally, a third literature (e.g. Barro and Lee, 1994) concludes that government size in turn does affect growth.

The novelty of our approach is based on linking these three literatures together by incorporating individual labor market decisions into a basic growth model. If risk-averse people choose their job, then wage volatility does play a role in their decision and our model reveals two distinct channels in which this uncertainty can affect growth: a positive direct effect (from precautionary savings) and a negative indirect effect (through government size). This suggests that an OLS framework is not sufficient to uncover the net effect of wage volatility on growth, as it suffers from endogeneity. One needs to consider the indirect channel of wage volatility on growth, operating through the size of the public sector.

Our empirical section uses a panel data set of 20 high-income OECD countries to test this theory. We show that indeed a simultaneous estimation of growth and government size is preferable to an OLS framework. Both the direct and the indirect channel are significant and remain robust to the addition of various control variables. Overall, the results suggest that a one standard deviation increase in wage volatility causes a 0.12 to 0.14 percent *increase* of GDP per capita.

Finally, our analysis also suggests a general component of analyzing volatility in the context of growth: if one ignores the indirect channel, the net impact of volatility on growth could be masked. Depending on whether the direct or the indirect effect dominate in a particular data set, one may find a positive, negative, or no effect of volatility on growth. This may provide an explanation for why previous analyses of volatility in the context of growth reached ambiguous conclusions.

The paper is organized as follows. Section 2 develops our theoretical intuition. Section 3 discusses the empirical analysis, consisting of methodology, a description of the data, the main

[2]For a comprehensive overview of determinants of government spending, see Shelton (2007) for instance.

results, and various robustness tests. Finally, section 4 concludes with a brief summary of results and possible implications.

2 The Theory

This section provides a theoretical intuition of the connection between wage volatility and economic growth. We first describe production and preferences in this closed economy, which produces two goods: the public good (g) and the private good (p). Workers face the discrete choice whether to earn a riskless wage in the public sector or contribute to production of the private good, which is by design subject to uncertainty (this setup follows Rodrik, 1998). A crucial extension from other models such as Turnovsky and Chattopadhyay (2003) is the worker's decision between two different jobs with their inherent features regarding volatility. For simplicity, we normalize the workforce to one. The crucial goal of this model is to endogenously determine the share (s) of people working in the public sector. Over defining growth, we then move to calculating the labor market equilibrium. Finally, we analyze how wage volatility affects this equilibrium and eventually economic growth.

2.1 Production and Wages

In our two-goods society, we assume two distinct production functions for the public and the private good. The public good only requires labor as an input in production, whereas the private good is produced with both labor and capital. Production of the public good is then determined by

$$Y_g = s^\gamma \tag{1}$$

with $0 < \gamma < 1$ symbolizing a technological production parameter. Wages in the public sector are given by the marginal product:

$$w_g = \gamma s^{\gamma-1}. \tag{2}$$

Production of the private good on the other hand follows an AK-technology:[3]

$$Y_p = AK + b(1 - s). \tag{3}$$

Wages from private sector employment are given by $b = w_p$ and follow a Brownian motion with a standard deviation σ:

$$db = \sigma dz, \tag{4}$$

where z stands for a normal Wiener process.[4]

2.2 Growth

From laying out the foundations of production and wages in our economy, we now turn to total output, given by

$$Y = Y_g + Y_P. \tag{5}$$

Once the labor market is in equilibrium, there will be no change over time in s, which means that GDP growth is entirely determined by the change in capital. Workers are identical in either sector and endowed with equivalent initial levels of wealth: $v_i(0)$ with $i \in \{g, p\}$ and time notation in parentheses. Total societal wealth consists of $K(t) = sv_g(t) + (1 - s)v_p(t)$ at any point in time.[5] With c_i being a respective worker's consumption and capital depreciating at the rate δ, the capital stock develops over time as

$$\frac{dK}{dt} = Y_p - \delta K - sc_G - (1 - s)c_p. \tag{6}$$

[3] Rodrik (1998) employs a general production function of which this is a special case. Even though allowing capital to perfectly substitute for labor is not necessarily realistic, it is convenient for calculations. It produces a constant rate of return to capital, but allows a stochastic wage.

[4] The production function described in equation 3 is a stochastic version of influential works in growth theory, like Romer (1986) or Jones and Manuelli (1990). Similar to Smith (1998), the stochastic variable follows a Brownian motion. A drawback here is the theoretical possibility of the wage becoming negative – a wel-known problem in the literature, which is thoroughly discussed in Wälde (2011). Also, notice that we are assuming a riskless wage in the public sector: all we need for our analysis to be consistent is a bigger volatility of the private wage.

[5] Unless essential, we omit time notation in the remainder of the model.

Notice that the government remains unproductive, as is common in many growth models, and only production of the private good contributes to growth. One could see the public good as spent by the government to maintain the infrastructure, as in Turnovsky (2000) for example.

2.3 The Workers' Decisions

Workers exhibit constant absolute risk aversion (CARA) and make their decision about where to work irreversibly at the beginning of time.[6] In this decision, they compare the resulting lifetime utility from working in either sector by choosing c_i to maximize

$$E\int_{t=0}^{\infty} -\frac{e^{-\theta t - ac_i}}{a} dt \tag{7}$$

subject to

$$\frac{dv_i}{dt} = rv_i + w_i - c_i. \tag{8}$$

θ stands for the agents' rate of time preference and a represents absolute risk aversion. Finally, let workers borrow and lend at a riskless rate, r. To solve the maximization problems in both sectors, we use the concept of dynamic programming (Merton, 1971), which allows us to analyze optimal continuous-time dynamic models under uncertainty.[7]

2.3.1 Working For The Government

Notice that when contemplating a government position, a worker only faces one state variable: wealth v_g. Were one to work in the riskless public sector, then solving (7) would lead to an optimal consumption of

$$c_g^* = \frac{\theta - r}{ar} + rv_g + w_g, \tag{9}$$

which is a linear function of wealth and wage, plus an intercept determined by her rate of time preference in combination with the return to capital and her degree of risk aversion. To assess

[6] If wage is random, this is a classic problem in precautionary savings. The only utility function allowing for a closed-form solution for consumption here is CARA.

[7] For detailed derivations of the Bellman equation and following results plus the transversality conditions for both sectors, please see the appendix.

the overall benefit from working for the government, we calculate the worker's value function evaluated at time zero:

$$J\left[v_g(0)\right] = -\frac{e^{\frac{r-\theta}{r} - arv_g(0) - aw_g(0)}}{ar}, \tag{10}$$

which measures the expected future utility of pursuing the optimal savings path.

2.3.2 Working in the Private Sector

Considering a job in the private market is slightly more complicated, since one also faces a stochastic wage (w_p) as a state variable. This maximization problem is a standard precautionary savings model in continuous time. After solving the Bellman equation (please see appendix for details) optimal consumption becomes

$$c_p^* = \frac{\theta - r}{ar} - \frac{a\sigma^2}{2r} + rv_p + w_p. \tag{11}$$

Once again, consumption is a linear function of wealth and wage, equivalent to the public sector wage. Only the intercept behaves differently compared to the public sector: the entire consumption profile shifts down by a risk premium ($\frac{a\sigma^2}{2r}$) for working in the stochastic private sector. Thus, uncertainty causes consumers to save more at any point in time, everything else equal. Finally, the expected lifetime benefit of working in the private sector is given by the value function:

$$J\left[v_p(0), w_p(0)\right] = -\frac{e^{\frac{r-\theta}{r} + \frac{a^2\sigma^2}{2r} - arv_p(0) - aw_p(0)}}{ar}. \tag{12}$$

Notice that the difference between the private and the public wage is exactly the risk premium for working in the private sector: $w_p = w_g + \frac{a\sigma^2}{2A}$.

2.4 Equilibrium in the Labor Market

Naturally, everybody chooses the sector which gives her the highest expected lifetime utility. In practice, workers allocate themselves in both sectors, just until value functions (equations 10 and 12) are equalized.[8] This allows us to pin down the equilibrium in the labor market with the share of people working for the government becoming

$$s^* = \left(\frac{\gamma}{b(0) - \frac{a\sigma^2}{2A}} \right)^{\frac{1}{1-\gamma}}. \tag{13}$$

Not surprisingly, better public sector technology (a higher γ) increases the size of government, whereas a higher initial wage in the private sector $[b(0)]$ reduces s. We can noticeably see the impact of risk on s^*: higher risk aversion (a) leads to more people choosing the safer public sector wage. Similar conclusions can be drawn from the variance of the private sector wage (σ^2). Since in equilibrium $w_p = w_g + \frac{a\sigma^2}{2A}$, the denominator of (13) is guaranteed to be positive, given (2). This also ensures $s^* < 1$. In fact, 2 potential equilibria spring from (13):

1. The specialized equilibrium from $\gamma = b(0) - \frac{a\sigma^2}{2A}$ and thus $s^* = 1$.

2. The diversified equilibrium from $\gamma < b(0) - \frac{a\sigma^2}{2A}$ and $0 < s^* < 1$.

The former depicts a very special case, where public sector wages are either astronomically high, private sector compensation is very low, and/or the risk from working in the private sector is tremendous.[9] The more realistic scenario appears to be the second case.

2.5 The Effects of Wage Volatility on Growth

After deriving optimal consumptions and the labor market equilibrium, we are now ready to consider how wage volatility affects economic growth. Simplifying (5) by using (6) and rearranging gives

$$\frac{dY}{dt} = -\frac{\theta - A}{a} - s^* w_g A + (1 - s^*)\left(\frac{a\sigma^2}{2}\right) - \delta K A. \tag{14}$$

Now how does wage volatility affect growth? Differentiating (14) with respect to σ^2 provides the answer:[10]

[8] In equilibrium, wages equal the marginal product. Similarly, the interest rate is equal to the marginal product of capital when the bond market is in equilibrium: $r = A$.

[9] One could only think of totalitarian or strict communist countries, where this might be the case.

[10] Notice that we are technically comparing 2 otherwise identical economies, with the only difference being a higher volatility in private sector wages in one of them.

$$\frac{\partial(\frac{dY}{dt})}{\partial\sigma^2} = (1-s^*)\frac{a}{2} - \frac{\partial s^*}{\partial\sigma^2}\left(w_g A + \frac{a\sigma^2}{2}\right). \tag{15}$$

The first term indicates the positive direct effect caused by lower consumption of private sector workers: higher wage volatility encourages them to save more. The second term summarizes both components of the negative indirect effect on growth, coming from the change in the composition of the labor market: (1) $(-\frac{\partial s^*}{\partial\sigma^2} w_g A)$ is the compensation of workers who now prefer the riskless wage in the public sector over the volatile private pay. (2) Since these workers now earn a riskless wage, they have no incentive for precautionary savings anymore $(-\frac{\partial s^*}{\partial\sigma^2}\frac{a\sigma^2}{2})$.

Overall, (15) predicts an ambiguous net effect of private sector wage volatility on growth since the positive direct and the negative indirect effect point in opposite directions. In reality, the net result will also depend on various country specific issues, for example the flexibility of the labor market in terms of regulations and laws. For instance, a rigid labor market structure diminishes $\frac{\partial s^*}{\partial\sigma^2}$. Finally, one crucial assumption of our model is the choice between working in the public or private sector, which could be unrealistic, especially in poorer countries. Thus, our model might naturally be better suited for the analysis of developed economies. The empirical part of the paper will now try to determine the validity of the above predictions.

3 Empirical Analysis

3.1 Methodology

We now proceed to testing if wage volatility (wv in the following; detailed derivations in section 3.2) does in fact affect economic growth and if both suggested channels can be observed in the data. Using equation 14, we choose government size (in the following $lgov$) as a proxy for total spending on public sector employees ($s^* w_g$). Adding other notorious growth determinants, we start by estimating growth (gr) in a single equation framework for country i at time t as[11]

$$gr_{i,t} = \alpha_1 + \alpha_2 wv_{i,t-1} + \alpha_3 lgov_{i,t} + \alpha_4 x_{i,t-1} + \alpha_5\lambda_i + \alpha_6\phi_{i,t} + \delta_{i,t}. \tag{16}$$

[11] gr is defined as the growth rate per capita divided by 100.

Following recommendations from Temple (1999) among others, we use lagged values of the explanatory variables in order to deal with a simultaneity problem prevalent in the growth literature. x contains growth determinants found to be significant in previous works. Following Mirestean and Tsangarides (2009), this includes openness to trade ($lopen1$), investment ($inv1$), GDP per capita ($lgdp1$), inflation ($infl1$), population growth ($popgr1$), life expectancy ($llife$), schooling ($lschool1$), the real exchange rate ($lexch1$), and debt ($ldebt1$).[12] In addition, x contains the growth rate of the previous two years ($gr1$ and $gr2$). To ensure we are not picking up labor market effects other than the volatility of wages, we also include the unemployment rate ($unempl1$) in x.[13] $lgov$ enters the growth equation following our theoretical model and previous works, such as Barro and Lee (1994). Equation 14 predicts a negative effect of government spending on growth. λ captures country-fixed effects, since we do expect unique national aspects (e.g. geography, climate, cultural and historical aspects) to affect growth differently across countries. In addition, looking at the variety of countries and their individual developments, we allow them to grow differently over time, with ϕ capturing country-specific time trends. Finally, δ constitutes the error term.

Our theoretical model predicts an ambiguous sign of the coefficient associated with wv (α_2), as the direct and indirect effect point in opposite directions, and a negative sign attached to the coefficient of $lgov$ (α_3). From equation 16, we then show that government size is in fact endogenous and a simultaneous estimation should be preferred, as suggested by our theoretical model in section 2. Thus, we also need to appropriately determine government spending as

$$lgov_{i,t} = \beta_1 + \beta_2 wv_{i,t-1} + \beta_3 gr_{i,t} + \beta_4 z_{i,t-1} + \beta_5 \lambda_i + \beta_6 \phi_{i,t} + \epsilon_{i,t}. \tag{17}$$

Following Shelton (2007), z contains openness to trade ($lopen1$), GDP per capita ($lgdp1$), and population size ($lpop1$). In addition, we add government size of the previous two years ($lgov1$ and $lgov2$) to z. Rodrik (1998) introduced trade openness as a potential determinant of the public

[12] Throughout the empirical section all variables starting with an l denote the natural logarithm, whereas a number at the end of a variable name displays the amount of years the variable is lagged. For the exact derivation of all variables, please see tables 2 and 3. Durlauf et al. (2005) give a good summary of instrumental variables in their appendices 3 and 4, where lagged values for (i) investment from Bond et al. (2010), (ii) inflation from Li and Zou (2002), (iii) trade as share of GDP (i.e. openness) from Edwards (2001) and Amable (2000), and (iv) GDP from Rousseau (2000) among others are mentioned.

[13] We further consider relative wage levels in the robustness checks.

sector, whereas Alesina and Wacziarg (1998) provide an explanation why bigger countries might have smaller public sectors on a per capita basis. Wagner's Law suggests a positive relationship between richer countries and government size. To capture this, we include both GDP per capita (in z) and the growth rate (gr) as regressors.

A simultaneous estimation of equations 16 and 17 proves to be feasible, as both equations are identified by unique dependent variables. For the growth regression, these are most importantly $gr1$, $gr2$, but also $inv1$, $infl1$, $popgr1$, $llife$, $lschool1$, $lexch1$, and $ldebt1$. $lgov1$, $lgov2$, and $lpop1$ are our unique determinants of government size.[14] Finally, since omitted variables could affect both equations, the error terms in (16) and (17) are subject to correlation. Therefore, we incorporate the seemingly unrelated regression equations model (SUR) to extend the 2SLS to a 3SLS system. With this general framework in mind, we now turn to describing our data.

3.2 Data

Table 1 summarizes our data set of 623 yearly observations from 20 countries. All of them fall under the definition of high-income OECD countries, which sets this data set apart from others such as Turnovsky and Chattopadhyay (2003), who specifically analyze developing countries. As mentioned in the introduction, this sample appears more suitable for our theoretical setup with the suggested labor market choices and also follows from the availability of reliable data. Table 2 provides a summary of all variables used and their method of computation, whereas table 3 shows detailed sources. Our most important variable is also the most difficult one to compute: private sector wage volatility. We follow several steps in order to obtain an accurate measurement here:

1. We take the natural logarithm of the "Business Sector Labor Compensation per Employee, excluding Agriculture" index as a measurement of private sector wages (w_P).[15]

2. We use the Hodrick-Prescott filter to decompose each country's time series (w_P) into a trend ($\bar{w}_P$) and a cycle term ($\tilde{w_P}$). Squaring the cycle term provides a measurement for

[14] Correlation coefficients (not displayed here) indicate that lagged values of government size are highly correlated with current government size, but not with growth; the respective argument holds for lagged values of growth.

[15] A problem of this analysis is the exclusion of the agricultural sector in private wages. However, country-fixed effects and country-specific time trends should reasonably control for this shortcoming.

the volatility of private sector wages ($\tilde{w}_P^2$) for each observation.[16]

3. Since government wages may not always be an entirely riskless source of income (as assumed in the theoretical part), we need to control for the volatility of public sector wages. In the absence of exact data on public sector wages, we apply steps 1 and 2 to the index of "Total Economy Labor Compensation per Employee" to obtain a proxy for public sector wage volatility ($\tilde{w}_G^2$).[17]

4. The difference between the volatility of private sector wages ($\tilde{w}_P^2$) and the volatility of public sector wages ($\tilde{w}_G^2$) results in a measurement for the excess wage volatility in the private sector: $(\tilde{w}_P^2) - (\tilde{w}_G^2) = wv_{it}$ in equations (16) and (17).

The fact that wv_{it} can become negative allows for cases where *public* sector wages are in fact more volatile. Table 2 reveals that the average excess wage volatility of the private sector across the entire sample is only slightly positive, underlining the importance of controlling for public sector wage volatility.

The growth rate, government expenditure per capita, openness to trade, GDP per capita, and investment per capita come from the Penn World Table 6.3.[18] Population, life expectancy, tertiary school enrollment (gross percentage), and the real effective exchange rate index are extracted from the World Development Indicators, provided by the World Bank. Finally, inflation (CPI percentage changes to previous period in 2005 constant prices), government debt (as percent of GDP), and the unemployment rate (harmonised) come from the OECD database. We apply the natural logarithm to most variables in order to facilitate comparability, as noted in table 2.

[16]We use a value of $\lambda_{HP} = 100$ for the Hodrick-Prescott filter, as is common in the literature, e.g. Backus and Kehoe (1992). One main concern of decomposing time series is the end-of-sample problem: observations close to the beginning (the end) of each series might be biased as data is only available for the future (the past). Following Watson (2007), we use an AR(1) growth rate model and extend each series by 4 data points in both directions before applying the filter.

[17]Even though private compensation is included here as well, it only constitutes a part of this index. Hence, a change in the volatility of private wages, holding everything else constant, will have a bigger effect on business sector labor compensation. The volatility of public wages on the other hand will only be captured in total economy wages.

[18]For a discussion why we choose PWT 6.3 over PWT 7, see for instance Breton (2012). For a general discussion about versions of the PWT see Johnson et al. (2012).

Figure 1 provides some basic descriptive graphs of our data. Graphs a) and b) plot averages of excess wage volatility against averages of growth and government size for our sample countries. Noticeably, Slovakia has a strong *negative* private sector excess wage volatility, which means that Slovakian public sector wages are actually more volatile than private sector wages in the available time frame of 1994 – 2007. As Slovakia separated from the Czech Republic in 1993 and then joined the European Union in 2004, one might speculate that political reasons sparked this uncertain development in the public sector. On the other end of the spectrum, New Zealand is standing out with strong positive excess wage volatility. This suggests that the private sector of New Zealand did in fact show increased excess volatility in private sector salaries over our available time frame of 1970 – 2007. The fitted lines in both a) and b) indicate that the cross-country correlation between wage volatility and growth is negative and almost non existent between wage volatility and government size. However, given the variety of other – potentially significant – determinants in either equation, this plain correlation merely contains minor explanatory power.

Moving to graph c), we notice that the plain correlation between the average size of the public sector and the average growth rate is negative. Finally, to give a basic idea of temporal developments, graph d) displays average excess wage volatility over time. Private sector wages appeared to be more volatile (relative to public sector wages) in the time periods 1975 – 1981 and 1995 – 2005, with calmer times occurring in 1982 – 1995. From these basic descriptive statistics and graphs, we now move to our main results.

3.3 Basic OLS Results

As mentioned above, we start by estimating equation (16) separately in an OLS framework. Table 4 displays 6 different specifications, adding control variables moving from left to right. We start with a basic estimation, only using wage volatility, government size and lagged growth rates as regressors, before adding fixed effects and control variables subsequently. At first glance, wage volatility (wv) does not seem to have any significant effect. Only in the final specification (6) does wage volatility become significant in predicting growth. Note however that we are losing over 40 percent of our sample, moving from 603 observations to 346 eventually, which is owed to missing data points among control variables. Judging from these preliminary OLS results, one might not suspect wage volatility to have any mentionable impact on growth. As a next step, we now test whether there is in fact endogeneity present, as suggested in equations (16) and (17). The results from the Durbin-Wu-Hausmann (DWH) test for endogeneity are displayed at the bottom of each regression in table 4. The significance of the DWH test in all specifications provides strong evidence that OLS is in fact not ideal and a simultaneous estimation should be preferred.

3.4 3 SLS Results

Moving from OLS to the preferred 3SLS framework allows us to specifically test for the direct and indirect channels of wage volatility, as suggested in the theoretical model. Table 5 displays our main regressions using the 3SLS system, where we estimate growth and government size (equations 16 and 17) simultaneously. Here again, we subsequently add country-specific time trends and control variables moving from left to right. We immediately notice wage volatility as a significantly positive predictor of growth – a marked difference to the mostly insignificant results from table 4. This suggests that the direct effect of volatility on growth was in fact masked in the OLS framework. Once we control for endogeneity, wage volatility does have a positive direct effect on growth, presumably through precautionary savings as implied by our theory. The effect appears not only qualitatively stronger, but also in terms of quantity. OLS estimations from table 4 generated a coefficient between 0.026 – 0.034, whereas the magnitudes in table 5 range from 0.030 – 0.043. With the magnitude of point estimates being higher in the 3SLS case, this points out the classical measurement error in the RHS variable, which we correct for by using simultaneous estimation. The (negative) indirect effect working through government size is now accounted for and the pure direct effect is revealed. Looking at the suggested indirect effect, wage volatility does have a positive and significant effect on government size, which in turn affects growth in a negative way. This confirms the power of uncertainty in the demand for the public good and/or public sector jobs, as predicted by our model.

The conclusions from these results are twofold. First, there is a qualitative interpretation. Were one to rely on OLS only, the effects of wage volatility are easily discarded as insignificant. However, the real effects are masked, as both the direct and the indirect effect (through the size of government) are mixed together. The fact that they point in different directions dilutes the overall impact of volatility and might return an insignificant coefficient. Once this endogeneity is accounted for, both channels are in fact significant and wage volatility does have noticeable effects on growth.

Second, there is a quantitative interpretation. Even though the magnitude of the coefficient on wage volatility is difficult to interpret – given our derivation of its measurement – our results allow a crude calculation of overall effects. Considering specifications (4) and (6) in table 5, we can calculate the overall effect of an increase in wage volatility on growth. In fact, our results suggest that a one standard deviation increase of excess private sector wage volatility (relative to public sector wage volatility) leads to an increase in GDP per capita by 0.12 or 0.14 percent respectively. For example, given a GDP of US$ 15 trillion in the United States, this one standard deviation makes a difference of 18 billion US dollars. With these main results in mind, we now take a closer look at wage levels across our sample.

3.5 Robustness Checks

The following discussion looks at various robustness checks, each of them using the same set of control variables as in specifications (4) and (5) of table 5. First, we include the relative wage level of the private sector into the analysis to check whether it may be a wage premium driving our results and not volatility. Second, we incorporate time fixed effects to see whether global (or OECD-wide) shocks may drive our results.[19] Finally, we focus on the choice of $\lambda_{HP} = 100$, as Ravn and Uhlig (2002) suggest a different value of $\lambda_{HP} = 6.25$ to adjust for the sensitivity of the trend portion when using annual time series data. Specifications (1) and (2) incorporate wage levels as a control variable to both equations. Intuitively, if the excess wage premium of holding a private sector job over public employment is remarkable, one might accept a higher wage volatility in return. Thus, in line with our measurement for the excess wage volatility of the private sector, we now include a measurement for the wage premium from working in the private sector. Specifically, we divide the difference between "Business Sector Labor Compensation per Employee, excluding Agriculture" and "Total Economy Labor Compensation per Employee" for country i at time t by "Total Economy Labor Compensation per Employee." This gives us a measurement of the excess wage premium from working in the private sector, which, in

[19]We thank an anonymous referee for pointing out both of these aspects.

accordance with our framework, we lag by one year to obtain $wlevel_{it}1$. The results indicate that a higher wage premium from working in the private sector has negative effects on growth. As for wage volatility of private sector wages, our main conclusions remain robust to the inclusion of wage levels, as we only note a slight decrease in magnitudes of the coefficients.

In our second robustness check, we focus on time effects. Recall that our main estimations use country-specific time trends, yet do not specifically control for any time-specific aspects. However, global shocks such as the oil crisis in the 1970s could well affect macroeconomic variables and their volatility. Including time fixed effects in specifications (3) and (4) leaves our main results untouched. On the margin this inclusion strengthens the direct effect both in terms of significance and in magnitude and slightly weakens the impact of the indirect effect. One reason could be that government size tends to be relatively inflexible in the short run, leaving less year-to-year variation for our predicted indirect effect to unfold.

Moving to the final specifications of table 6, we now focus on our choice of λ_{HP} in detrending wages, determining the sensitivity to short-term fluctuations. When dealing with annual variables, it is mostly recommended to imply a value of $\lambda_{HP} = 100$ (for instance Backus and Kehoe, 1992), which is what we use in our main specifications. However, Ravn and Uhlig (2002) advocate $\lambda_{HP} = 6.25$. Re-estimation of our main results using $\lambda_{HP} = 6.25$ to detrend excess private sector wage volatility again confirms our main results, although volatility barely turns insignificant in predicting the size of government in the final specification. A closer look reveals that this is mostly owed to higher standard errors on the volatility coefficients, which more than double when using $\lambda_{HP} = 6.25$. In terms of magnitudes, we observe a strengthening of both the direct and the indirect effect.

In summary, signs and significance levels across our robustness checks in table 6 do indicate a general robustness of our results with respect to the inclusion of wage levels and the choice of λ_{HP} in detrending wages.

4 Conclusions

This paper takes a closer look at the connection between wage volatility and the growth rate of GDP per capita. We are extending previous theoretical works, such as Turnovsky and Chattopadhyay (2003) or Devereux and Smith (1994), by incorporating the individual's labor market decision into a simple growth model. By modeling a person's choice whether to earn a riskless wage in a government job or a volatile private sector wage, we combine previous intuitions about the effects of volatility on both economic growth and the size of the public sector. Our theoretical results suggest two distinct channels in which wage volatility affects growth: a positive direct and a negative indirect way. The former stems from a precautionary savings motive, whereas the latter comes from the distribution in the labor market and the fact that public sector wages are riskless.[20]

In the second half of the paper, we analyze the growth effects of wage volatility in a sample of over 600 observations from 20 high-income OECD countries. As predicted, pure OLS estimation with wage volatility as a regressor does in fact mask the real net impact of volatility on growth. Once we account for the indirect channel through government size in a 3SLS setting, both channels are significant. In total, our results indicate a positive net effect on growth, with the positive direct effect dominating the negative indirect effect. As a crude estimation, a one standard deviation of private sector wage volatility seems to increase GDP per capita by around 0.12 to 0.14 percent. Using the United States as an example, this comes out to the equivalent of 18 – 21 billion US dollars total.

Our results not only provide evidence of wage volatility having significant effects on growth, but also give a general orientation for analyzing other macroeconomic volatility measurements and their effects on growth. If one does not acknowledge the indirect channel and only regresses growth on volatility (plus the usual control variables), the net impact of volatility might be masked by endogeneity. In terms of policy recommendations, our main conclusion is that one needs to be cautious when inferring the effects of volatility on a country's growth rate. Even though our results suggest a positive link, we are only able to analyze 20 high-income countries over a limited time frame. Plus, our decision modeling appears to be more realistic for developed economies, where choices are generally broader in terms of career paths. Thus, one needs to be aware of country- and region-specific aspects, such as the structure of the labor market, when thinking about policies to control or unleash volatility. Our analysis aims to add to the

[20]This assumption of entirely riskless public wages can be relaxed to relatively less risk than working in the private sector.

understanding of how volatility affects major macroeconomic variables. Future research might consider using this basic framework to analyze (wage) volatility in a broader sample or in a region-specific context to potentially draw explicit policy responses.

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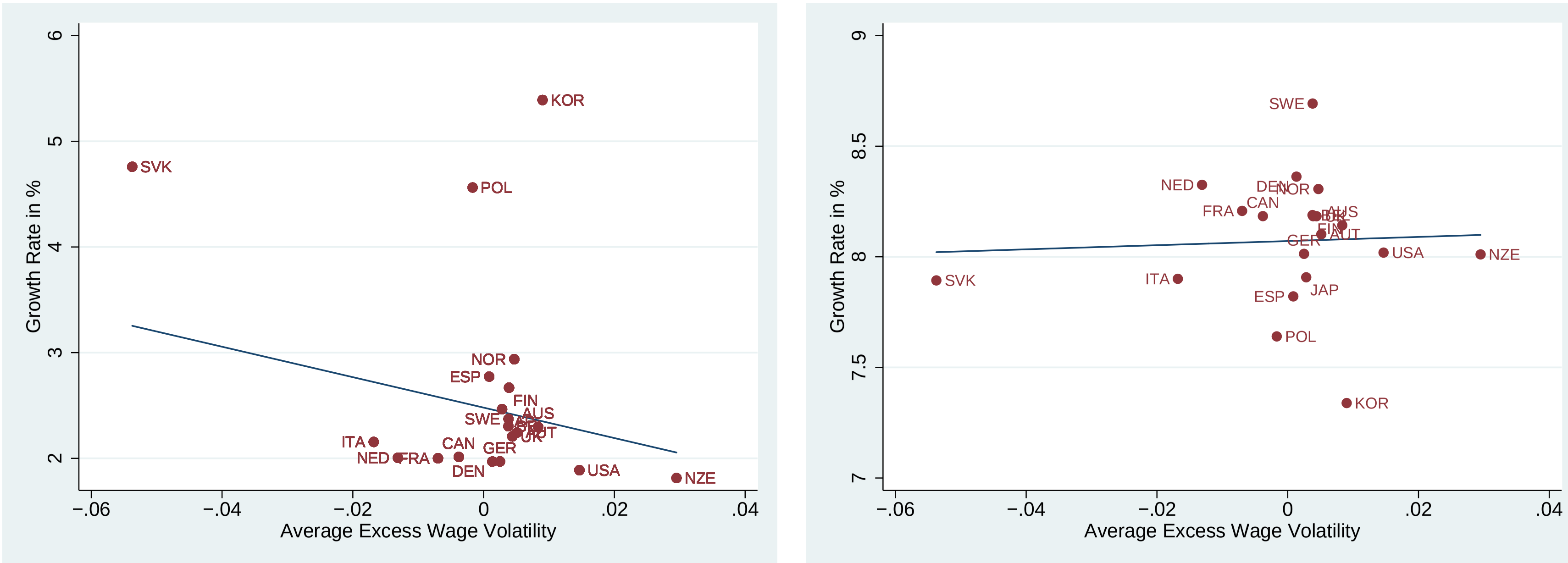
a) Growth vs. wage volatility

b) Government size vs. wage volatility



c) Government size vs. growth

d) Wage volatility over time

Figure 1: Descriptive graphs

Table 1: Sample countries and time frames

Country	Time Period	Observations
Australia	1984 – 2007	24
Austria	1976 – 2007	32
Belgium	1970 – 2007	38
Canada	1970 – 2006	37
Denmark	1970 – 2007	38
Finland	1970 – 2007	38
France	1970 – 2007	38
Germany	1972 – 2007	36
Italy	1970 – 2007	38
Japan	1970 – 2007	38
Korea	1985 – 2007	23
Netherlands	1970 – 2007	38
New Zealand	1989 – 2006	18
Norway	1970 – 2007	38
Poland	1992 – 2007	16
Slovakia	1994 – 2007	14
Spain	1980 – 2007	28
Sweden	1993 – 2007	15
United Kingdom	1970 – 2007	38
United States	1970 – 2007	38
N		623

Table 2: Summary statistics

Variable	Mean	Std. Dev.	Min	Max	N	Computation of Variable
gr	0.024	0.021	-0.098	0.103	603	(Growth Rate Laspeyres per capita)/100
lgov	8.093	0.309	6.785	8.731	603	Ln[(Gov't Share per capita/100)∗(GDPper capita)]
wv	0.001	0.041	-0.344	0.223	603	1. Ln(Business Sector Wages), 2. Decomposition of Wages ($\lambda_{HP} = 100$) for each country time series separately 3. Repeating steps 1 and 2 for total economy wages, 4. Squared cycle term from step 2 ($\tilde{w}_P^2$) – squared cycle term from step 3 ($\tilde{w}_G^2$) = excess volatility of private sector wages ($\tilde{w}^2$)
lopen	3.822	0.583	2.322	5.171	603	Ln(Openness)
lgdp	10.005	0.305	8.881	10.752	603	Ln(GDP per capita)
inv	8.734	0.36	7.007	9.638	603	Ln[(Investment Share per capita/100)∗(GDP per capita)]
infl	0.05	0.048	-0.009	0.461	603	(Inflation Rate)/100
popgr	0.537	0.451	-0.53	1.974	603	Population Growth Rate
lpop	10.063	1.238	8.125	12.606	603	Ln(Population)
llife	4.332	0.034	4.227	4.411	570	Ln(Life Expectancy)
lschool	3.695	0.461	2.524	4.585	532	Ln(Schooling)
lexch	4.58	0.123	4.137	4.968	528	Ln(Real Exchange Rate)
unempl	0.073	0.038	0.01	0.2	530	(Unemployment Rate)/100
ldebt	3.694	0.632	1.751	5.103	435	Ln[Total Central Government Debt (% GDP)]

Table 3: Data sources and variable derivations

Variable	Source	Description
Business Sector Labor Compensation per employee (PPP)	OECD	Excluding Agriculture, this variable is indexed to 100 in the year 2005 and contains the following occupations, labeled C-K (according to the ISIC): C: Mining and quarrying; D: Manufacturing; E: Electricity, gas and water supply F: Construction; G: Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods; H: Hotels and restaurants; I: Transport, storage and communications; J: Financial intermediation; K: Real estate, renting and business activities
Total Economy Labor Compensation per employee (PPP)	OECD	Indexed to 100 in the year 2005, the economic activities are derived from the ISIC.
Growth	Penn World Table 6.3 (PWT)	Growth Rate of Real GDP Laspeyres2 per capita (grGDPL2) in 2005 constant prices.
Government Share	Penn World Table 6.3	Government Share (kg) of Real GDP per capita, measured in percent in 2005 constant prices.
Openness	Penn World Table 6.3	Defined as Exports plus Imports divided by Real GDP per capita, Openness (openk) is measured in percent in 2005 constant prices.
Investment	Penn World Table 6.3	The investment share of Real GDP per capita (ki) is measured in 2005 constant prices.
Real GDP per capita	Penn World Table 6.3	Real GDP Laspeyres2 per capita (RGDPL) is measured in 2005 constant prices.
Inflation	OECD	Defined as the Consumer Price Index' (CPI, all items) percentage change from the previous period in 2005 constant prices.
Population Growth	World Development Indicators, World Bank	Population Growth (annual %)
Population Size	World Development Indicators, World Bank	Total population
Life Expectancy	World Development Indicators, World Bank	Life Expectancy at birth, total (years). From United Nations Population Division. 2009.
Schooling	World Development Indicators, World Bank	School enrollment, tertiary (% gross)
Real Exchange Rate	World Development Indicators, World Bank	Real effective exchange rate index (2005 = 100)
Unemployment Rate	OECD	Labour Force Statistics (MEI): Harmonised Unemployment Rates (HURs).
Government Debt	OECD	Total Central Government Debt (% GDP)

Table 4: OLS results. Dependent variable is the growth rate of GDP per capita (gr)

	(1) gr	(2) gr	(3) gr	(4) gr	(5) gr	(6) gr
wv1	0.027 (0.022)	0.030 (0.025)	0.028 (0.024)	0.028 (0.022)	0.026 (0.023)	0.034* (0.020)
lgov1	-0.014*** (0.004)	-0.059*** (0.016)	-0.038* (0.022)	-0.046** (0.023)	-0.092*** (0.027)	-0.057* (0.030)
gr1	0.364*** (0.082)	0.253*** (0.081)	0.307*** (0.080)	0.399*** (0.062)	0.378*** (0.062)	0.441*** (0.054)
gr2	-0.045 (0.049)	-0.132*** (0.045)	-0.020 (0.041)	0.003 (0.041)	0.082 (0.052)	0.028 (0.058)
lopen1			0.030*** (0.012)	0.022* (0.012)	0.027* (0.015)	-0.027 (0.019)
inv1			-0.049*** (0.013)	-0.055*** (0.013)	-0.056*** (0.015)	-0.062*** (0.017)
lgdp1			0.013 (0.037)	-0.018 (0.039)	-0.019 (0.038)	-0.014 (0.041)
infl1			-0.178*** (0.034)	-0.143*** (0.035)	-0.144*** (0.034)	-0.084* (0.045)
popgr1				0.004 (0.003)	0.002 (0.003)	0.000 (0.003)
llife1				0.637*** (0.185)	0.909*** (0.193)	1.365*** (0.206)
lschool1					-0.007 (0.006)	-0.008 (0.009)
lexch1					0.008 (0.009)	0.020 (0.012)
unempl1						-0.078 (0.081)
ldebt1						0.019*** (0.006)
Constant	0.127*** (0.031)	0.520*** (0.137)	0.508*** (0.182)	-1.743*** (0.656)	-2.614*** (0.676)	-4.752*** (0.736)
Country fixed effects	yes	yes	yes	yes	yes	yes
Country-specific time trend		yes	yes	yes	yes	yes
DWH-test for endogeneity	16.99***	15.96***	23.30***	21.91***	16.03***	3.68*
N	603	603	603	570	462	346
R^2	0.211	0.314	0.425	0.452	0.483	0.644

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: 3SLS results for growth of GDP/capita (*gr*) and government size (*lgov*)

	(1)	(2)	(3)	(4)	(5)	(6)
3SLS Results for Dependent Variable: gr						
wv1	0.041**	0.035*	0.030*	0.031*	0.032*	0.039**
	(0.019)	(0.019)	(0.017)	(0.017)	(0.017)	(0.017)
lgov	-0.015***	-0.068***	-0.032	-0.046*	-0.102***	-0.067**
	(0.004)	(0.016)	(0.024)	(0.025)	(0.028)	(0.034)
Control set 1	yes	yes	yes	yes	yes	yes
Control set 2			yes	yes	yes	yes
Control set 3				yes	yes	yes
Control set 4					yes	yes
Control set 5						yes
Country fixed effects	yes	yes	yes	yes	yes	yes
Country-specific time trend		yes	yes	yes	yes	yes
F-test joint insignificance of IVs[1]	7.07***	6.86***	28.11***	24.82***	18.05***	20.53***
3SLS Results for Dependent Variable: lgov						
wv1	0.066***	0.067***	0.052***	0.050***	0.056***	0.075***
	(0.017)	(0.017)	(0.016)	(0.016)	(0.018)	(0.021)
gr	0.165	-0.099	0.102	0.118	0.256***	0.276***
	(0.118)	(0.134)	(0.080)	(0.075)	(0.079)	(0.085)
Control set A	yes	yes	yes	yes	yes	yes
Control set B			yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes
Country-specific time trend		yes	yes	yes	yes	yes
F-test joint insignificance of IVs[2]	41698.06***	2612.40***	1124.90***	1124.90***	1124.90***	1124.90***
N	603	603	603	570	462	346

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Control set 1: $gr1$ and $gr2$. Control set 2: $lopen1$, $inv1$, $lgdp1$, and $infl1$. Control set 3: $popgr1$ and $llife1$. Control set 4: $lschool1$ and $lexch1$. Control set 5: $unempl1$ and $ldebt1$. Control set A: $lgov1$ and $lgov2$. Control set B: $lopen1$, $lgdp1$, $lpop1$. A number at the end of a variable stands for the amount of years this variables is lagged. [1]IVs are regressors exclusively used in the gr equation in the following 3SLS analysis: $grl1$, $grl2$, $lopen1$, $inv1$, $lgdp1$, $infl1$, $popgr1$, $llife1$, $lschool1$, $lexch1$, $unempl1$, and $ldebt1$. [2]IVs are regressors exclusively used in the $lgov$ equation in the following 3SLS analysis: $lgov1$ and $lgov2$.

Table 6: 3SLS results for growth of GDP/capita (gr) and government size ($lgov$)

	Including Wage Levels		Including Time Fixed Effects		$\lambda_{HP} = 6.25$	
	(1)	(2)	(3)	(4)	(5)	(6)
3SLS Results for Dependent Variable: gr						
wv1	0.031*	0.034*	0.044***	0.050***	0.089**	0.075*
	(0.017)	(0.017)	(0.015)	(0.014)	(0.042)	(0.041)
lgov	-0.050**	-0.112***	-0.042*	-0.081***	-0.050**	-0.108***
	(0.025)	(0.029)	(0.024)	(0.028)	(0.025)	(0.028)
wlevel1	-0.059	-0.103*				
	(0.055)	(0.054)				
Control sets 1, 2, and 3	yes	yes	yes	yes	yes	yes
Control set 4		yes		yes		yes
Country fixed effects	yes	yes	yes	yes	yes	yes
Country-specific time trend	yes	yes	yes	yes	yes	yes
Time effects			yes	yes		
3SLS Results for Dependent Variable: lgov						
wv1	0.050***	0.056***	0.047***	0.046***	0.079**	0.061
	(0.016)	(0.018)	(0.016)	(0.018)	(0.039)	(0.042)
gr	0.133*	0.262***	0.270***	0.451***	0.128*	0.268***
	(0.077)	(0.080)	(0.092)	(0.096)	(0.074)	(0.079)
wlevel1	-0.032	-0.020				
	(0.051)	(0.053)				
Control sets A & B	yes	yes	yes	yes	yes	yes
Country fixed effects	yes	yes	yes	yes	yes	yes
Country-specific time trend	yes	yes	yes	yes	yes	yes
Time effects			yes	yes		
N	570	462	570	462	570	462

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Control set 1: $gr1$ and $gr2$. Control set 2: $lopen1$, $inv1$, $lgdp1$, and $infl1$. Control set 3: $popgr1$ and $llife1$. Control set 4: $lschool1$ and $lexch1$. Control set A: $lgov1$ and $lgov2$. Control set B: $lopen1$, $lgdp1$, $lpop1$. A number at the end of a variable stands for the amount of years this variables is lagged.

5 Appendix

5.1 Working for the Government

To solve the agents' maximization problem, the Bellman equation presents a common method to address dynamic programming problems. In the public sector, the agent chooses c_g to maximize her utility, where wealth v_g represents her only state variable:

$$-\frac{e^{-ac_g}}{a} - \theta J(v_g) + J^{'}(v_g)(rv_g + w_g - c_g). \tag{5.1}$$

Taking the first derivative gives

$$c_g = -\frac{lnJ^{'}(v_g)}{a}. \tag{5.2}$$

As a next step, an 'educated guess' (in this case one might assume that the state variable v_g exhibits similar properties than the choice variable c_g) provides a possible solution to the value function, $J(v_g)$:

$$J(v_g) = -\frac{e^{-\beta_0-\beta_1 v_g}}{\beta_1}. \tag{5.3}$$

Taking the first derivative

$$J^{'}(v_g) = e^{-\beta_0-\beta_1 v_g} \tag{5.4}$$

allows us to rewrite the Bellman equation as

$$0 = -\frac{e^{-\beta_0-\beta_1 v_g}}{a} + \frac{\theta}{\beta_1}e^{-\beta_0-\beta_1 v_g} + e^{-\beta_0-\beta_1 v_g}(rv_g + w_g - \frac{\beta_0 + \beta_1 v_g}{a}). \tag{5.5}$$

Dividing by $e^{-\beta_0-\beta_1 v_g}$ gives

$$0 = -\frac{1}{a} + \frac{\theta}{\beta_1} + rv_g + w_g - \frac{\beta_0 + \beta_1 v_g}{a}. \tag{5.6}$$

From here, collect terms to conclude

$$\beta_1 = ar \tag{5.7}$$

and

$$\beta_0 = \frac{\theta - r}{r} + aw_g. \tag{5.8}$$

Using the above results for the optimal consumption and the value function leads to the results presented in the main text.

5.1.1 Transversality Condition for the Public Sector

In any infinite horizon dynamic optimization problem, the present value of the state variables is required to converge to zero as the planning horizon recedes towards infinity. From (5.1):

$$-\frac{\theta}{J}J + \frac{J^{'}}{J}(rv_g + w_g - \frac{\theta - r}{ar} - w_g - rv_g) < 0. \tag{5.9}$$

Using results for J and J' and simplifying gives a straight forward solution:

$$r > 0. \tag{5.10}$$

Hence, a positive interest rate is sufficient to fulfill the Transversality Condition for working in the public sector.

5.2 Working in the Private Sector

The Bellman equation from working in the private sector becomes slightly more busy, as she faces two state variables - wealth v_p and the stochastic private sector wage w_p:

$$-\frac{e^{-ac_p}}{a} - \theta J(v_p) + J_{vp}{}^{'}(rv_p + w_p - c_p) + J_{wp}{}^{''}\frac{\sigma^2}{2}. \tag{5.11}$$

Taking the first derivative then gives

$$c_p = -\frac{lnJ^{'}(v_p)}{a} \tag{5.12}$$

Similar to the above exercise, conjecture

$$J(v_p, w_p) = -\frac{e^{-\beta_0 - \beta_1 v_p - \beta_2 w_p}}{\beta_1}. \tag{5.13}$$

Similarly, the first derivative with respect to v_p becomes

$$J_{v_p}^{'} = e^{-\beta_0-\beta_1 v_p-\beta_2 w_p}. \tag{5.14}$$

Similarly,

$$J_{w_p}^{'} = \frac{\beta_2}{\beta_1} e^{-\beta_0-\beta_1 v_p-\beta_2 w_p} \tag{5.15}$$

and

$$J_{w_p}^{''} = \frac{{\beta_2}^2}{\beta_1} e^{-\beta_0-\beta_1 v_p-\beta_2 w_p} \tag{5.16}$$

constitute the respective derivatives with respect to w_p. Bringing these results back to the Bellman equation gives

$$\begin{aligned} 0 = &- \frac{e^{-\beta_0-\beta_1 v_p-\beta_2 w_p}}{a} + \frac{\theta}{\beta_1} e^{-\beta_0-\beta_1 v_p-\beta_2 w_p} + e^{-\beta_0-\beta_1 v_p-\beta_2 w_p}(r v_p + w_p - \frac{\beta_0 + \beta_1 v_p + \beta_2 w_p}{a}) \\ &- \frac{\sigma^2 {\beta_2}^2}{2\beta_1} e^{-\beta_0-\beta_1 v_p-\beta_2 w_p}. \end{aligned} \tag{5.17}$$

$$\tag{5.18}$$

Dividing by $e^(- \beta_0 - \beta_1 v_p - \beta_2 w_p)$ gives

$$0 = -\frac{1}{a} + \frac{\theta}{\beta_1} + r v_p + w_p - \frac{\beta_0 + \beta_1 v_p + \beta_2 w_p}{a} - \frac{\sigma^2 \beta_2^2}{2\beta_1}. \tag{5.19}$$

Then

$$\beta_1 = ar, \tag{5.20}$$

$$\beta_2 = a, \tag{5.21}$$

and

$$\beta_0 = \frac{\theta - r}{r} - \frac{a^2 \sigma^2}{2r}. \tag{5.22}$$

These results allow us to solve for the optimal consumption and the value function presented in the main text.

5.2.1 Transversality Condition for the Private Sector

Similarly to the public sector, but slightly busier, the following condition needs to hold in order to satisfy the Transversality Condition in the private sector:

$$-\frac{\theta J}{J} + \frac{J_{v_p}^{'}}{J}(rv_p + w_p - \frac{\frac{\theta}{r} - 1}{a} - rv_p - w_p) + \frac{J_{w_p}^{''}\frac{\sigma^2}{2}}{J} < 0. \quad (5.23)$$

Using results for J, and $J_{wp}^{''}$ plus an algebraic simplification gives the same result as in the public sector:

$$r > 0 \quad (5.24)$$

Again, a positive interest rate is enough to satisfy the Transversality Condition in the private sector.