The effects of wage volatility on growth

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ABSTRACT

This paper shows that the volatility of wages 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, ignoring indirect effects operating through government size may mask the real net effects of volatility on growth, which could result in misleading conclusions. Specific to wage volatility, our results suggest that the net effect on economic growth depends on both government size and the wage premium from working in the private sector. Within our sample, we find evidence for both – countries for which wage volatility is beneficial to growth and others for which it is detrimental.

1. Introduction

Labor markets of many economies today are marked by a variety of policies designed to lower temporary fluctuations of income (e.g. job protection laws or unemployment benefits). Most people prefer stable wages over stark fluctuations, exhibiting risk aversion. Consequently, wage volatility can play an important role in one's job selection, but also in consumption and savings decisions.[1] In aggregate then, these microeconomic decisions could have meaningful effects on an economy's overall performance. But even though macroeconomic variables are acknowledged as substantial drivers of economic growth, wage volatility has mostly been overlooked in this context.[2]

This paper contributes to the growth literature in two ways. First, we show, theoretically and empirically, that there exists both a direct and an indirect effect from wage volatility on a country's rate of economic growth. Second, our findings may explain why previous works could not agree whether various sorts of volatility stimulate or hamper economic growth. Especially acknowledging the existence of the indirect channel is crucial to understanding the net growth effects from volatility.

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[1] For instance, Fuchs-Schündeln and Schündeln (2005) point out the importance of risk-averse workers selecting into low-risk occupations. Turnovsky and Smith (2006) highlight the role of risk in determining consumption and precautionary savings.

[2] Various recent works underline the importance of macroeconomic variables in the growth context, such as Henderson et al. (2012a) focusing on nonlinearities or Durlauf et al. (2008) and Mirestean and Tsangarides (2009) addressing model uncertainty and endogeneity. For a general discussion of growth determinants one might consider Barro and Lee (1994), Alesina et al. (1996), Barro (1996), Barro and Sala-i Martin (1997), or Frankel and Romer (1999). Excellent summaries are provided by Temple (1999), Durlauf and Quah (1999), or Sala-i Martin et al. (2004).

Previous works on other sorts of volatility in macroeconomic variables find positive, negative, or even non-existent effects on growth. For instance, Ramey and Ramey (1995) suggest negative effects from volatile growth rates itself, being one of the first papers to conclusively relate the business cycle to economic growth. Similarly, Turnovsky and Chattopadhyay (2003) conclude that monetary as well as terms-of-trade volatility lowers growth. However, Devereux and Smith (1994), Caporale and McKiernan (1998), and Canton (2002) suggest positive growth effects from volatility in the economy. Finally, Dawson and Stephenson (1997), Chatterjee and Shukayev (2005), and Posch and Wälde (2011) argue that volatility has no effect at all on growth. Thus, the role of volatility in macroeconomic variables with respect to economic growth remains subject to discussion.

Our theoretical section adds to previous models (e.g. Turnovsky and Chattopadhyay, 2003) by incorporating an individual's job choice into a basic growth model, focusing on the role of wage volatility in this decision. The model allows us to dissect the mechanisms at work in detail. We find that wage volatility can affect economic growth through two distinct channels. There exists a positive direct effect, but also a negative indirect effect, operating through the size of the public sector. The direct effect can be traced back to an increase (a decrease) in precautionary savings once volatility increases (decreases).[3] As for the indirect channel, higher volatility in private sector wages first raises the demand for public sector jobs, therefore increasing government size.[4] A bigger government in turn lowers growth rates, as labor resources are withdrawn from the productive private sector.[5] As both the direct and the indirect effect operate in opposite directions, a researcher could find a positive, a negative, or no effect at all from volatility on growth, if growth is estimated in a single equation framework only. The indirect effect operating through government size needs to be accounted for. Although our theoretical findings apply to wages only, one may speculate about similar dynamics for other sorts of volatilities.

In the empirical section, we use panel data for 20 high-income OECD countries to test this theory. We show that indeed a simultaneous estimation of growth and government size is preferable to a single estimation framework. Both the direct and the indirect channel are significant and remain robust to the addition of various control variables. Were one to ignore the endogeneity of government size, the basic OLS results suggest no significant effect from wage volatility and the importance of volatile wages could be dismissed. Finally, an extension of our main results indicates that the net effect of wage volatility on growth depends on two country-specific parameters, namely government size and the wage premium from working in the private sector. Higher values in both variables increase the likelihood of the net effect being negative. We find evidence for both – countries with a positive and a negative net effect.

The remainder of 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 results, and 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 a 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 goal of this model is to endogenously determine the share (s) of people working in the public sector. After defining growth, we then move to calculating the labor market equilibrium. Finally, we analyze how wage volatility affects this equilibrium and eventually economic growth.

Addressing these issues requires the solution of a dynamic model of precautionary savings in the presence of wage uncertainty. It is well known however (Blanchard and Mankiw, 1988; Hall, 1988; Caballero, 1990, 1991; Weil, 1993; Smith, 2002) that the only closed-form solution to this problem requires a set of highly restrictive assumptions, namely, (1) constant absolute risk aversion, (2) normally distributed wage income, and (3) a constant rate of return to financial assets.[6] This forces us to construct a general equilibrium model with these features. While they are not particularly appealing, adopting them permits us to reveal with stark clarity the intuitive mechanisms by which wage volatility affects growth. These mechanisms will inform the empirical tests in the second half of the paper.

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[3] The direct effect found here is akin to Devereux and Smith (1994), who suggest that international risk sharing (and thus lower volatility) in terms of portfolio choices reduces precautionary savings, which in turn lowers growth.

[4] In addition, one might think of a rising demand for public policy programs alleviating the increased volatility in wages, although our model does not capture this mechanism. The phenomenon of increased uncertainty in the economy affecting the demand for public goods is also mentioned by Rodrik (1998). Generally, Shelton (2007) provides a comprehensive overview of determinants of government spending.

[5] Also see Barro and Lee (1994) for the effects of government size on growth.

[6] Caballero (1990) incorporates mean-reverting wage income in a discrete-time model of precautionary savings. Following Smith (2002), we could do this too in our continuous-time setting, but it would add little to the model. Weil (1993), also in discrete-time, uses CARA risk preferences, but allows for a constant elasticity of intertemporal substitution. We could also add this twist in continuous-time, but it would not add much to the problem at hand.

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[7]:

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

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.[8]

2.2. Growth

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.[9] With c_i being a respective worker's consumption and capital depreciating at the rate δ, the capital stock develops over time as

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

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.[10] 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

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

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[7] 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.

[8] The production function described in Eq. (3) is a stochastic version of influential works in growth theory, like Romer (1986) or Jones and Manuelli (1990). Smith (1998) used this linear production function in order to provide a general equilibrium justification for the CARA/normal precautionary savings, that can be solved. Notice that Eq. (3) yields both a constant rate of return to capital (A) and, given the Wiener process in (4), normally distributed wage income. A drawback here is the theoretical possibility of the wage becoming negative – a well-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.

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

[10] 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.

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 dynamic programming (Merton, 1971), which allows us to analyze optimal continuous-time dynamic models under uncertainty.[11]

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

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

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

$$J[v_g(0)] = -\frac{e^{\frac{r-\theta}{r} - ar v_g(0) - a w_g(0)}}{ar}, \tag{10}$$

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

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

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 $\left(\frac{a\sigma^2}{2r}\right)$ 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:

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

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 (Eqs. (10) and (12)) are equalized.[12] 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, as the denominator of (13) decreases. 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 unrealistically high, private sector compensation is very low, and/or the risk from working in the private sector is exceptional.[13] The more realistic scenario appears to be the second case.

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

[12] 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: $r = A$.

[13] One could only think of totalitarian or strict communist countries, where this might be the 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[14]:

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

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) $\left(-\frac{\partial s^*}{\partial\sigma^2} w_g A\right)$ 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 $\left(-\frac{\partial s^*}{\partial\sigma^2}\frac{a\sigma^2}{2}\right)$.

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 determine whether wage volatility (wv; detailed derivations in Section 3.2) does in fact affect economic growth and if both suggested channels can be observed in the data. Using Eq. (14), we choose government size ($lgov$) as a proxy for total spending on public sector employees ($s^* w_g$). Adding other proven growth determinants, we start by estimating growth (gr) in a single equation framework for country i at time t as[15]

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

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 ($ldebt1$).[16] In addition, x contains the growth rate of the previous 2 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.[17] $lgov$ enters the growth equation following our theoretical model and previous works, such as Barro and Lee (1994). Eq. (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 suggests a positive direct and a negative indirect effect from volatility on growth. Thus, when estimating Eq. (16) in an OLS framework the projected sign of α_2, the coefficient associated with wage volatility, is not clear a priori. Following our model, we further expect a negative sign attached to the coefficient of $lgov$ (α_3). Over a single estimation of Eq. (16), we then test whether government size is in fact endogenous and a simultaneous estimation should be preferred, as suggested by our theory. After confirming endogeneity, we then proceed to estimating

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[14] 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.

[15] gr Is defined as the growth rate of GDP per capita.

[16] 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.

[17] We further consider wage premia between private and public sector wages in the robustness checks.

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

growth and government size simultaneously, where wage volatility enters both equations as a regressor. We specify government size 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 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 Eqs. (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.[18] 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 approach. 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).[19]
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 the volatility of private sector wages ($\tilde{w}_P^2$) for each observation.[20]

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[18] 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.

[19] 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.

[20] 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.

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 (λ_{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 $(\bar{w}_P^2)$ – squared cycle term from step 3 $(\bar{w}_G^2)$ = excess volatility of private sector wages $(\bar{w}^2)$
wpremium	.023	.038	−.096	.123	603	Wage premium from working in the private sector: (Business Sector Wages – Total Economy Wages)/(Total Economy Wages)
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	Labor Force Statistics (MEI): Harmonized Unemployment Rates (HURs)
Government Debt	OECD	Total Central Government Debt (% GDP)

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 $(\bar{w}_G^2)$.[21]

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[21] 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.
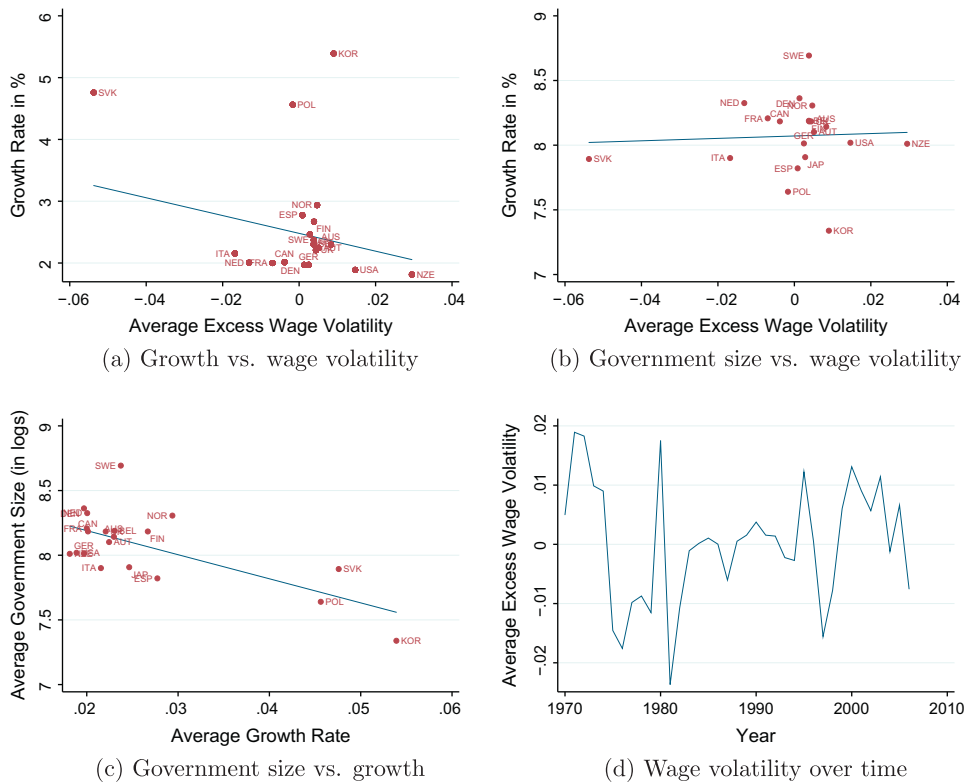
(a) Growth vs. wage volatility

(b) Government size vs. wage volatility

(c) Government size vs. growth

(d) Wage volatility over time

Fig. 1. Descriptive graphs.

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 Eqs. (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.[22] 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 (harmonized) come from the OECD database. We apply the natural logarithm to most variables in order to facilitate comparability, as noted in Table 2.

Fig. 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 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

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[22] 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. (2013).

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

	(1)	(2)	(3)	(4)	(5)	(6)
OLS Results for Dependent Variable: gr						
wv1	0.027	0.030	0.028	0.028	0.026	0.034[*]
	(0.022)	(0.025)	(0.024)	(0.022)	(0.023)	(0.020)
lgov1	−0.014***	−0.059***	−0.038[*]	−0.046**	−0.092***	−0.057[*]
	(0.004)	(0.016)	(0.022)	(0.023)	(0.027)	(0.030)
gr1	0.364***	0.253***	0.307***	0.399***	0.378***	0.441***
	(0.082)	(0.081)	(0.080)	(0.062)	(0.062)	(0.054)
gr2	−0.045	−0.132***	−0.020	0.003	0.082	0.028
	(0.049)	(0.045)	(0.041)	(0.041)	(0.052)	(0.058)
lopen1			0.030***	0.022[*]	0.027[*]	−0.027
			(0.012)	(0.012)	(0.015)	(0.019)
inv1			−0.049***	−0.055***	−0.056***	−0.062***
			(0.013)	(0.013)	(0.015)	(0.017)
lgdp1			0.013	−0.018	−0.019	−0.014
			(0.037)	(0.039)	(0.038)	(0.041)
infl1			−0.178***	−0.143***	−0.144***	−0.084[*]
			(0.034)	(0.035)	(0.034)	(0.045)
popgr1				0.004	0.002	0.000
				(0.003)	(0.003)	(0.003)
llife1				0.637***	0.909***	1.365***
				(0.185)	(0.193)	(0.206)
lschool1					−0.007	−0.008
					(0.006)	(0.009)
lexch1					0.008	0.020
					(0.009)	(0.012)
unempl1						−0.078
						(0.081)
ldebt1						0.019***
						(0.006)
Constant	0.127***	0.520***	0.508***	−1.743***	−2.614***	−4.752***
	(0.031)	(0.137)	(0.182)	(0.656)	(0.676)	(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.
[*] $p < 0.10$.
[**] $p < 0.05$.
[***] $p < 0.01$.

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 Eq. (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 Eqs. (16) and (17). The results from the Durbin–Wu–Hausmann (DWH) test are displayed at the bottom of each regression in Table 4 and their significance suggests the presence of endogeneity. This confirms our suspicion that a simultaneous estimation framework should be preferred over a single equation model.

3.4. 3SLS 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 approach, where

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.
Notes: Control set 1: *gr*1 and *gr*2. Control set 2: *lopen*1, *inv*1, *lgdp*1, and *infl*1. Control set 3: *popgr*1 and *llife*1. Control set 4: *lschool*1 and *lexch*1. Control set 5: *unempl*1 and *ldebt*1. Control set A: *lgov*1 and *lgov*2. Control set B: *lopen*1, *lgdp*1, *lpop*1. 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: *grl*1, *grl*2, *lopen*1, *inv*1, *lgdp*1, *infl*1, *popgr*1, *llife*1, *lschool*1, *lexch*1, *unempl*1, and *ldebt*1. [2]IVs are regressors exclusively used in the *lgov* equation in the following 3SLS analysis: *lgov*1 and *lgov*2.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

we model growth and government size (Eqs. (16) and (17)) simultaneously. Here again, we subsequently add country-specific time trends and control variables moving from left to right.[23] 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 and 0.034, whereas the magnitudes in Table 5 range from 0.030 to 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 instruments. 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. Once this endogeneity is accounted for, both channels are significant with wage volatility having noticeable effects on growth.

Second, there is a quantitative interpretation. Even though the magnitude of wage volatility is difficult to interpret given our derivation of its measurement, the results allow a crude calculation of overall effects. Considering specifications (4) and (6) in Table 5, our results suggest that a one standard deviation increase of excess private sector wage volatility (relative to public sector wage volatility) would lead 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.

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[23] Adding in time fixed effects does not change sign or significance levels of our main variables. Results are available upon request from the authors.

Table 6
Robustness checks and extensions. 3SLS results for growth of GDP/capita (*gr*) and government size (*lgov*).

	λ_{HP} = 6.25		Including wage premium		Interaction with wage premium	
	(1)	(2)	(3)	(4)	(5)	(6)
3SLS Results for dependent variable: gr						
wv1	0.089**	0.075*	0.031*	0.034*	0.046**	0.046**
	(0.042)	(0.041)	(0.017)	(0.017)	(0.018)	(0.019)
lgov	−0.050**	−0.108***	−0.050**	−0.112***	−0.048**	−0.109***
	(0.025)	(0.028)	(0.025)	(0.029)	(0.025)	(0.029)
wpremium1			−0.059	−0.103*	−0.033	−0.081
			(0.055)	(0.054)	(0.055)	(0.055)
wv1 × premium1					−1.421***	−0.973*
					(0.487)	(0.512)
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
3SLS results for dependent variable: lgov						
wv1	0.079**	0.061	0.050***	0.056***	0.054***	0.054***
	(0.039)	(0.042)	(0.016)	(0.018)	(0.017)	(0.020)
gr	0.128*	0.268***	0.133*	0.262***	0.119	0.267***
	(0.074)	(0.079)	(0.077)	(0.080)	(0.079)	(0.082)
wpremium1			−0.032	−0.020	−0.024	−0.023
			(0.051)	(0.053)	(0.052)	(0.054)
wv1 × wpremium1					−0.404	0.135
					(0.474)	(0.543)
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
N	570	462	570	462	570	462

Standard errors in parentheses.
Notes: wv1 × wpremium1: interaction term between *wv*1 and *wpremium*1. Control set 1: *gr*1 and *gr*2. Control set 2: *lopen*1, *inv*1, *lgdp*1, and *infl*1. Control set 3: *popgr*1 and *llife*1. Control set 4: *lschool*1 and *lexch*1. Control set A: *lgov*1 and *lgov*2. Control set B: *lopen*1, *lgdp*1, *lpop*1. A number at the end of a variable stands for the amount of years this variables is lagged.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Section 3.6 will provide a deeper insight into which effect dominates when. The following section assesses the validity of our main results across two robustness checks.

3.5. Robustness checks

This section looks at a couple of additional specifications, each of them using the same set of control variables of specifications (4) and (5) of Table 5. Specifically, Table 6 displays results when re-considering λ_{HP} (the main parameter in the application of the Hodrick–Prescott filter) and including the premium from working in the private sector (the difference of wages in the private sector over public sector salaries).

First, we focus on the choice of λ_{HP}, which determines the sensitivity to short-term fluctuations in the Hodrick–Prescott filter. Although the benchmark value for λ_{HP} is 100, Ravn and Uhlig (2002) advocate λ_{HP} = 6.25. Re-estimations of our main results with λ_{HP} = 6.25 are displayed in columns (1) and (2) of Table 6. Our main results are mostly confirmed, although volatility barely turns insignificant in predicting government size in the final specification. A closer look reveals that this is owed to higher standard errors of the volatility coefficients, which more than double when using λ_{HP} = 6.25. In terms of magnitudes, we even observe a strengthening of both the direct and the indirect effect.

Second, we add the difference between private and general wages (labeled *wpremium*1) as an independent variable to Eqs. (16) and (17) to check whether a wage premium may drive our results and not volatility. Intuitively, if the wage premium of holding a private sector job is substantial, one might become less sensitive to wage volatility. Even though our model predicts that the difference between private and public sector wages should only come from a risk premium, one can think of other exogenous factors causing a wage premium, such as personal preferences or job availability. 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 for the wage premium from working in the private sector in percentage terms, for which, in accordance with our econometric framework, we use the lagged value $wpremium_{i,t-1}$. The results are displayed in specifications (3) and (4) of Table 6 and indicate that a higher wage premium from working in the private sector has negative effects on growth. Our
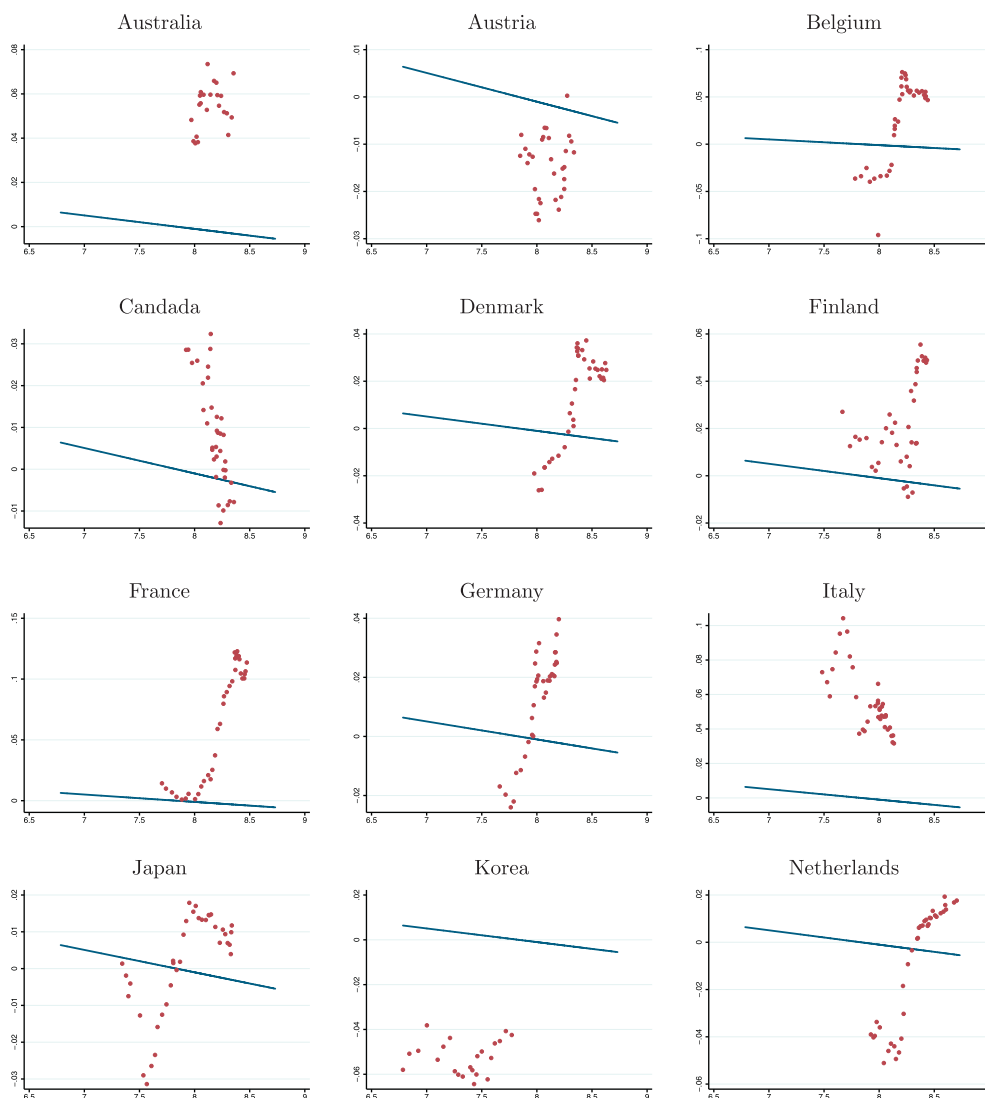
Fig. 2. Net effects from wage volatility. *Notes*: x-axis: government size (*lgov*), y-axis: wage premium (*wpremium*1). Values over the threshold level (solid line) represent observations where wage volatility (*wv*1) is predicted to have decreased economic growth. Values under the solid line are observations where wage volatility is predicted to have increased growth.

main conclusions remain robust to the inclusion of the private sector wage premium, as we only note a slight decrease in magnitudes of the coefficients. Thus, our findings appear to be driven by wage volatility, not private sector wage premia.

3.6. Evaluating net effects

Finally, we consider an extension from our main results in specifications (5) and (6) of Table 6 in order to provide practical conclusions for our sample countries.[24] Even though the private sector wage premium does not have a direct effect on growth in our analysis, we find that it does alter the relative magnitudes of the effects from wage volatility. Including an interaction term of wage volatility and the wage premium (*wv*1 × *wpremium*1) reveals that with a higher premium from working in the private sector, the direct effect of wage volatility on growth diminishes. In other words, higher relative wages may reduce the importance of precautionary savings. The indirect effect is not affected by the addition of both the wage premium and

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[24] We thank an anonymous referee for pointing out this avenue of considering the wage premium, both as a robustness check and a parameter for potential nonlinearities in our results.
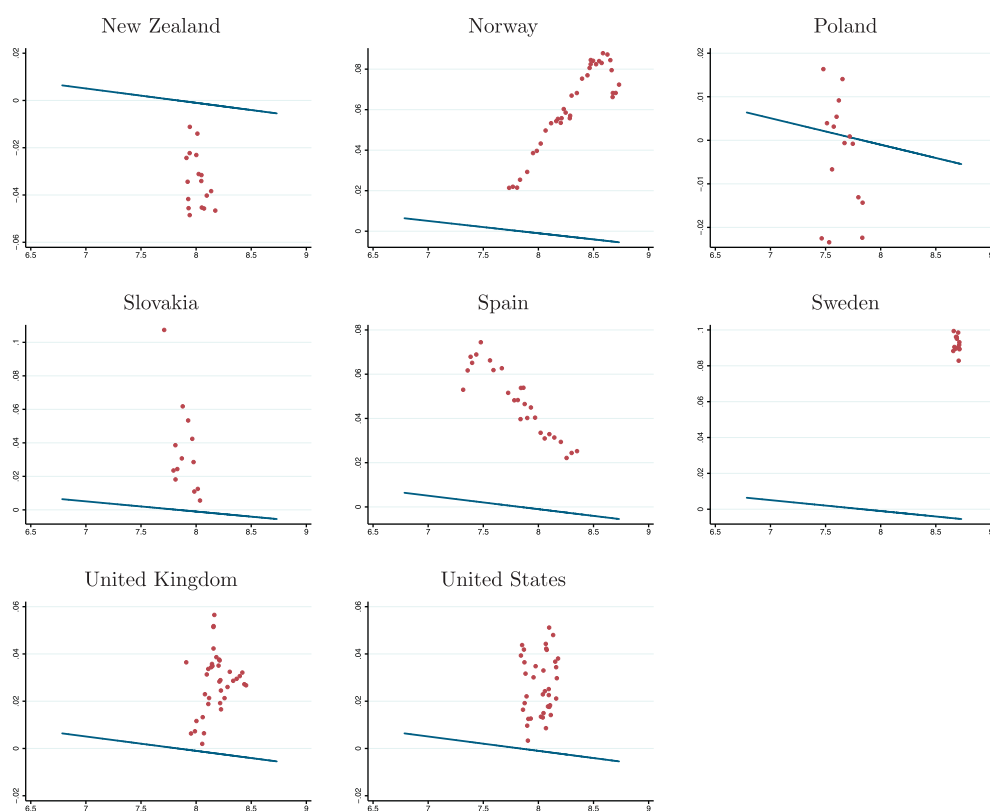
Fig. 2 (*continued*)

the interaction term. Thus, different countries could experience different net effects from wage volatility on growth, revealing an interesting nonlinearity across the parameters government size and wage premia.[25]

What does this mean for our results? In essence, there are two parameters affecting the relative magnitude of the direct and the indirect effect from wage volatility and growth: government size (through the indirect effect) and the wage premium from working in the private sector (through the direct effect).[26] The net effect will then depend on both of these parameters. Fig. 2 builds on regression (6) of Table 6, plotting government size (*lgov*) against the wage premium (*wpremium*1) for all our observations, sorted by countries. The solid line represents the threshold level, where observations under (over) the line indicate a positive (negative) net effect from wage volatility on growth.

A close look at Fig. 2 shows that wage volatility should have lowered growth over the respective sample periods in Australia, Canada, Finland, France, Italy, Norway, Slovakia, Spain, Sweden, the United Kingdom, and the United States. Especially in Norway and Sweden, both government size and the wage premium are substantially higher than in the other sample countries. In Austria, Korea, and New Zealand on the other hand wage volatility should have had a positive net effect on economic growth. Especially in Korea, this result can be traced back to a smaller government, whereas in Austria and New Zealand the wage premium is low or even negative in the respective time frames. In the other countries, we notice a mix of years with positive and negative net growth effects from wage volatility.

In summary, there is evidence that the evaluation of the net effect from wage volatility on growth depends on country-specific parameters. Specifically, countries with bigger governments and a high wage premium from working in the private sector are more likely to incur negative growth effects from higher wage volatility. Positive net effects can be expected in countries with smaller governments and a lower wage premium.

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[25] Recently, the growth literature has started to point out nonlinearities across several dimensions, such as Reinhart and Rogoff (2010) relating growth to public debt or Henderson et al. (2012b) in the context of financial development. Further, Cohen-Cole et al. (2012) looks at foreign aid and its link to the quality of policy in the recipient country.
[26] Notice that this wage premium can also turn negative, similar to our measurement of wage volatility, as it is possible for public wages to exceed private wages in practice.

4. Conclusions

This paper looks at the connection between wage volatility and the growth rate of GDP per capita. We extend 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.[27]

In the second half of the paper, we analyze growth effects from 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 and robust. Further, we notice substantial heterogeneity in between countries as to which effect dominates. In addition to the mediating role of government size, the wage premium from working in the private sector plays an important role. The importance of the positive direct effect diminishes with a higher wage premium. A possible explanation for this phenomenon could be that precautionary savings become less sensitive to income fluctuations once relative earnings are high. Across our sample, the net effect of wage volatility on growth is persistently negative in 11 out of 20 sample countries, whereas three countries are suggested to have had solely positive net effects throughout their respective sample periods.

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 in the growth context. If one does not acknowledge the indirect channels 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 beneficial or detrimental growth effects from volatility. Data availability only allows us 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-specific aspects, such as the structure of the labor market and wage differences, when thinking about policies to control or unleash wage volatility.

Appendix A

A.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:

$$0 = \max\ c_g - \frac{e^{-ac_g}}{a} - \theta J(v_g) + J'(v_g)(rv_g + w_g - c_g). \tag{4.18}$$

Taking the first derivative gives

$$c_g = -\frac{\ln J'(v_g)}{a}. \tag{4.19}$$

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, $J(v_g)$:

$$J(v_g) = -\frac{e^{-\beta_0 - \beta_1 v_g}}{\beta_1}. \tag{4.20}$$

Taking the first derivative

$$J'(v_g) = e^{-\beta_0 - \beta_1 v_g} \tag{4.21}$$

allows us to rewrite the Bellman equation as

$$0 = -\frac{e^{-\beta_0 - \beta_1 v_g}}{a} + \frac{\theta}{\beta_1} e^{-\beta_0 - \beta_1 v_g} + e^{-\beta_0 - \beta_1 v_g}\left(rv_g + w_g - \frac{\beta_0 + \beta_1 v_g}{a}\right). \tag{4.22}$$

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

$$0 = -\frac{1}{a} + \frac{\theta}{\beta_1} + rv_g + w_g - \frac{\beta_0 + \beta_1 v_g}{a}. \tag{4.23}$$

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

From here, collect terms to conclude

$$\beta_1 = ar \tag{4.24}$$

and

$$\beta_0 = \frac{\theta - r}{r} + aw_g. \tag{4.25}$$

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

A.2. Transversality condition for the public sector

The solution to this problem must also satisfy a Transversality Condition (TVC) requiring convergence of the value function. A sufficient condition for the TVC to be satisfied is that $J(v_g)$ not grow too fast relative to the discount rate θ:

$$-\theta + \frac{J'}{J} E dv_g < 0 \tag{4.26}$$

Using the value function and consumption function derived above and reported in the text, this inequality simplifies to

$$r > 0. \tag{4.27}$$

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

A.3. 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:

$$0 = \max \; c_p - \frac{e^{-ac_p}}{a} - \theta J(v_p) + J'_{v_p}(rv_p + w_p - c_p) + J''_{w_p}\frac{\sigma^2}{2}. \tag{4.28}$$

Taking the first derivative then gives

$$c_p = -\frac{\ln J'(v_p)}{a} \tag{4.29}$$

Similar to the above exercise, conjecture

$$J(v_p, w_p) = -\frac{e^{-\beta_0 - \beta_1 v_p - \beta_2 w_p}}{\beta_1}. \tag{4.30}$$

Similarly, the first derivative with respect to v_p becomes

$$J'_{v_p} = e^{-\beta_0 - \beta_1 v_p - \beta_2 w_p}. \tag{4.31}$$

Similarly,

$$J'_{w_p} = \frac{\beta_2}{\beta_1} e^{-\beta_0 - \beta_1 v_p - \beta_2 w_p} \tag{4.32}$$

and

$$J''_{w_p} = \frac{\beta_2^2}{\beta_1} e^{-\beta_0 - \beta_1 v_p - \beta_2 w_p} \tag{4.33}$$

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

$$0 = -\frac{e^{-\beta_0 - \beta_1 v_p - \beta_2 w_p}}{a} + \frac{\theta}{\beta_1} e^{-\beta_0 - \beta_1 v_p - \beta_2 w_p} + e^{-\beta_0 - \beta_1 v_p - \beta_2 w_p}\left(rv_p + w_p - \frac{\beta_0 + \beta_1 v_p + \beta_2 w_p}{a}\right) \tag{4.34}$$

$$-\frac{\sigma^2 \beta_2^2}{2\beta_1} e^{-\beta_0 - \beta_1 v_p - \beta_2 w_p}. \tag{4.35}$$

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

$$0 = -\frac{1}{a} + \frac{\theta}{\beta_1} + rv_p + w_p - \frac{\beta_0 + \beta_1 v_p + \beta_2 w_p}{a} - \frac{\sigma^2 \beta_2^2}{2\beta_1}. \tag{4.36}$$

Then

$$\beta_1 = ar, \tag{4.37}$$
$$\beta_2 = a, \tag{4.38}$$

and

$$\beta_0 = \frac{\theta - r}{r} - \frac{a^2 \sigma^2}{2r}. \tag{4.39}$$

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

A.4. 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:

$$-\theta + \frac{J'_{v_p}}{J} E d v_p + \frac{J''_w}{J} \frac{E w_p^2}{2} < 0. \tag{4.40}$$

Using results for J, and J''_{w_p} plus an algebraic simplification gives the same result as in the public sector:

$$r > 0 \tag{4.41}$$

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

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