J Econ Inequal (2009) 7:29–54
DOI 10.1007/s10888-007-9062-z

Informatization, voter turnout and income inequality

Ryo Arawatari

Received: 1 September 2006 / Accepted: 6 July 2007 / Published online: 22 September 2007
© Springer Science + Business Media B.V. 2007

Abstract In recent years, voter turnout has been decreasing in most industrial countries, and about 40% of all electors abstain from voting. This may affect income inequality and the GDP growth rate through a redistribution policy determined by majority voting. In this paper, we explore the reasons for this continuing decrease in voter turnout and assess its social costs. We conclude that informatization lowers voter turnout by generating an information overload, and that a decrease in voter turnout lowers GDP growth by limiting income redistribution.

Keywords Income inequality · Information · Informatization · Voter turnout · Voting

JEL Classification D31 · O15 · O41 · P16

1 Introduction

In recent years, voter turnout has been decreasing in most industrial countries, and about 40% of all electors abstain from voting. Moreover, a common feature of industrial countries is that agents with low income, low human capital or limited information tend to abstain from voting. Figure 1 shows the movement of voter turnout in the US and UK from 1918 to 2005. It shows that the evolution of voter turnout is described by an inverse U-shaped curve, and that voter turnout has been decreasing in recent years. Nardulli et al. [25] also point out that voter turnout in

R. Arawatari (✉)
Graduate School of Economics, Osaka University, 1-7 Machikaneyama,
Toyonaka, Osaka, 560-0043, Japan
e-mail: ege001ar@mail2.econ.osaka-u.ac.jp

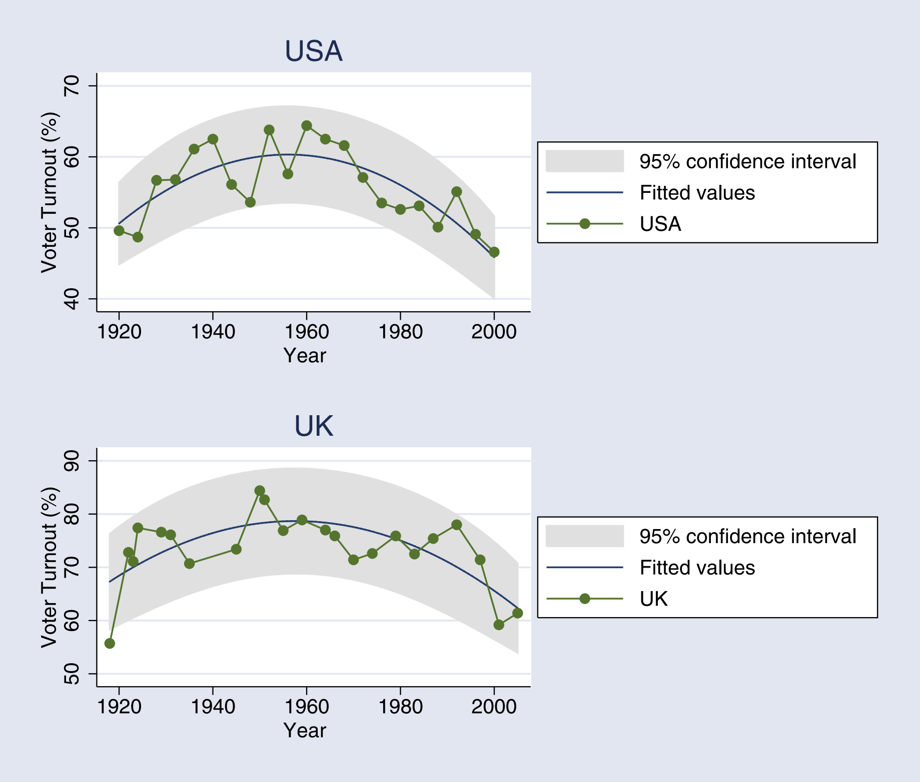

Fig. 1 Movements in voter turnout

the US is described by an inverse U-shaped curve; voter turnout in the US increased from 1920 to 1960 and decreased from 1960 on.

The continuing decrease in voter turnout may affect income inequality and the GDP growth rate through a redistribution policy determined by majority voting. Although there have been many studies of the relationship between the endogenous determination of the tax rate and income inequality [2, 18, 26, etc.], to our knowledge, there has been no study of the reasons for the continuing decrease in voter turnout and the social costs of this decline.

Many studies of voting behavior have their origins in Downs [7]. He develops the well-known "paradox of voting", which explains why rational voters invest their personal time and energy in voting despite the minimal probability of their vote being a decisive in majority voting. Many political scientists and economists have analyzed and presented solutions to the "paradox of voting".

Downs [7] presents the simplest solution to this paradox. He introduces a term, D, to represent the value of democracy continuing. He argues that, if everyone abstains from voting, democratic institutions would cease to exist. Therefore, some people may vote to perpetuate democratic institutions. This idea is expanded by Riker and Ordeshook [29], who develop the notion of "citizen duty". They argue that "citizen duty" represents the value of doing one's duty as a citizen, and voters obtain a value, D, from voting regardless of the outcome. Feddersen and Pesendorfer [8, 9] proposes a game-theoretic voting model. They investigate how asymmetries in information across voters affect voting behavior and the election result. In their model, voting is costless for all voters and, thus, abstention cannot be explained by differences in the cost of voting. By contrast, Ghirardato and Katz [13] focus not on the quantity, but on the quality of information. They explain how the quality of the information available to voters affects their voting behavior. Their key result is that the voter who is averse to ambiguity considers abstention strictly optimal when the candidates' policy positions are both ambiguous and they are "ambiguity complements". Lohmann [19, 20] develops a signaling model of mass political action. She shows that some self-interested voters have incentives to undertake costly political action to provide private information to the political leader, whereas others abstain from voting, hoping to benefit if the leader makes an uninformed decision.

These approaches all predict that agents with low income, low human capital or limited information tend to abstain from voting (cross-sectional differences in voting behavior). This prediction is supported by many experimental studies. For example, using cross-section data over a 32-year period on 3100 US counties, Filer et al. [10] find that better educated people have a greater tendency to vote. Using data on counties where many African Americans live, Smith [32] shows that voter turnout is positively correlated with the average academic level. Using a unique data set based on telephone interviews with Copenhagen voters, carried out in 2000, Lassen [17] finds that being informed has a statistically significant effect on the propensity to vote.

Thus, the "paradox of voting" seems to have been resolved by these theoretical and experimental studies. However, the problem with these studies is that, because they analyze a static model, they cannot explain the observed decrease in voter turnout (over-time differences in voting behavior). Since average incomes, human capital and the degree of informatization have increased in most developed countries, in a dynamic context, the above models suggest that voter turnout increases with economic growth. However, this result is not consistent with the empirical evidence that voter turnout has been decreasing in most developed countries. This suggests another paradox. In a static context, voters with low incomes, low human capital or limited information tend to abstain from voting; this is supported by existing theoretical and empirical studies. However, from a dynamic context, a decreasing voter turnout has been accompanied by increases average incomes, human capital and the degree of informatization. We refer to this as the 'new paradox of voting'. Hence, to analyze the dynamic decline in voter turnout, we need another model of the choice between voting and abstaining.

In this paper, we present a new dynamic model that provides a solution to the 'new paradox of voting'. First, we introduce the concepts of 'informatization' and the 'cost of collecting information' into a standard static voting model and show that our model is consistent with earlier studies cited above. Second, we apply the static model to a discrete-time nonoverlapping generations model and analyze the dynamic evolution of voter turnout. In this way, we demonstrate that our model can explain the cross-sectional differences and the over-time differences in voting behavior simultaneously; it can offer a solution to the 'new paradox of voting'. Our model also allows us to analyze: (1) the relationship between voter turnout and informatization; (2) the social costs of a decrease in voter turnout; and (3) the effect of informatization on income inequality. We conclude that informatization generates an inverse U-shaped pattern in voter turnout, and that a decrease in voter turnout reduces the GDP growth rate by limiting income redistribution.[1]

This paper is organized as follows. The model in this paper consists of two parts: the voting model and the economic model. In Section 2, we discuss the voting model. We explain the relationship between informatization and the cost of collecting information and show that voters and abstainers may coexist. In Section 3, we develop the economic model. We demonstrate that an increase in abstention lowers the GDP growth rate. In Section 4, we combine the voting model and the economic model and derive a politico-economic equilibrium. In Section 5, we present numerical examples and their implications. Section 6 concludes the paper.

2 The voting model

In this section, we analyze a simple but novel static voting model. We introduce informatization and the cost of collecting information into the standard spatial voting model. We argue that our model is consistent with existing theoretical and experimental studies and that it offers a solution to the 'new paradox of voting'.

2.1 Multidimensional policy and voters' preferences

We consider the following spatial voting model. We denote a multidimensional policy by $\boldsymbol{P}_t = (\tau_t, \boldsymbol{Z}_t) \in [0, 1] \times \mathbb{R}^l_+$ $(l \geq 2)$, where t is the time index, τ_t is the tax rate and $\boldsymbol{Z}_t$ is a vector of policies except for taxation. For example, $\boldsymbol{Z}_t$ includes foreign policy, environmental policy and defense policy. We assume that τ_t and $\boldsymbol{Z}_t$ are defined over the Euclidean space.

There is a continuum of voters $i \in [0, 1]$ who decide between voting under the pure majority rule[2] and abstaining from voting. Let us assume that the utility function of a voter i is given by:

$$U_t^i = u\left(c_t^i, h_{t+1}^i \middle| \tau_t\right) + V(I_t, h_t^i) + W(\boldsymbol{Z}_t), \tag{1}$$

where c_t^i is consumption, h_t^i and h_{t+1}^i are human capital at period t and $t+1$, respectively, τ_t and $\boldsymbol{Z}_t$ are implemented policies at period t.[3] I_t is the degree of informatization. This variable represents the number of sources of information, including the circulation of newspapers, books and magazines, the number of television channels and the number of websites. We assume that I_t is defined over the Euclidean space.

Each voter's utility comprises three components. First, $u(c_t^i, h_{t+1}^i | \tau_t)$ represents utility from the individual's own consumption and the human capital of that person's

[1] We do not claim that ours is the only possible explanation of the observed facts. We aim to describe the significant effects of informatization on voter turnout and present our findings as a possible explanation of the observed facts.

[2] See Persson and Tabellini [27] for details on the pure majority rule. Persson and Tabellini [26], Alesina and Rodrik [2], and Li and Zou [18] also assume this rule.

[3] Implemented policies are determined by majority voting.

offspring (altruism).[4] Second, $V(I_t, h_t^i)$ represents utility from voting. This is important in explaining the long-run decline in voter turnout. Third, $W(\boldsymbol{Z}_t)$ represents the utility obtained from policies other than taxation. This is not the main focus of the analysis, but it is included to illustrate the importance of informatization in the remainder of this section.

2.2 Citizen duty and information cost

We specify $V(I_t, h_t^i)$ in Eq. 1 as:

$$V(I_t, h_t^i) = \begin{cases} D - IC(I_t, h_t^i) & \text{if vote,} \\ 0 & \text{if abstain,} \end{cases} \tag{2}$$

where each variable is defined in what follows.

The first term, D, is the utility derived from voting per se. The idea that utility is obtained from voting was initially developed by Downs [7] and expanded by Riker and Ordeshook [29]. Using the term "citizen-duty", Riker and Ordeshook [29] argue that D represents the value of doing one's duty as a citizen, by, for example, expressing support for one's country and democratic institutions. Voters consider that voting is a citizen's right and duty, and thus they value voting per se whatever the outcome.[5] We assume that the utility represented by D is common to all voters and is time invariant.

We also assume that, when voters vote, they must have information about the policies, $\boldsymbol{P}_t = (\tau_t, \boldsymbol{Z}_t)$, and incur a cost, $IC(I_t, h_t^i)$, of collecting information. We can interpret $IC(I_t, h_t^i)$ as the opportunity cost of the leisure time used to collect information about policies, $\boldsymbol{P}_t = (\tau_t, \boldsymbol{Z}_t)$. Note that, if there is only taxation policy, voters can easily evaluate the policy because they know the optimal tax rate. However, to evaluate non taxation policies, $\boldsymbol{Z}_t$, voters need information about policy content and objectives. For example, a voter considering what is the best foreign policy must collect information about the current diplomatic situation and the expected outcome of implementing a particular foreign policy. Then, the voter must forgo some leisure time to collect information. This opportunity cost is $IC(I_t, h_t^i)$, which is henceforth termed 'information cost'. Note that we do not claim that information requirements for informed voting are high. As Lupia [22], Lupia and McCubbins [23] and Popkin [28] argue, voters use little information about political issues very effectively, therefore information requirements for informed voting are actually low. However, this fact does not mean that we can ignore the information cost. As Aldrich [1] points out, turnout is a low-cost, low-benefit decision-making problem. Small changes in costs and benefits alter the voting-abstention choice for the electorate. Therefore, when we consider the voting-abstention choice of the electorate, we cannot ignore the information cost. As already mentioned, $I_t > 0$ represents the degree of informatization: the larger is I_t, the greater is informatization. Equation 2 shows that the degree of informatization affects the information cost. Note that I_t is an endogenous variable; we discuss I_t in detail in Section 2.5.

[4] This is explained in detail in Section 3.

[5] The term D is also used in Fiorina [11], Crain and Deaton [6], Hinich [14], Aldrich [1], Kanazawa [16], among others.

We specify the information cost as follows:

$$IC(I_t, h_t^i) = \frac{\chi}{(h_t^i)^{\zeta}} \cdot \left\{ \underbrace{AI_t^{-\psi}}_{\text{access cost}} + \underbrace{BI_t^{\phi}}_{\text{filtering cost}} \right\}, \tag{3}$$

where $\chi > 0$, $\zeta > 0$, $\phi > 1$ and $\psi > 0$ are parameters. The information cost, $IC(I_t, h_t^i)$, consists of two components: the 'access cost' and the 'filtering cost'. First, $AI_t^{-\psi}$ is the cost of accessing information, and is decreasing in the degree of informatization. This cost can be interpreted as a measure of the time required to access information sources. An increase in the number of information sources reduces the time taken to access information sources and, hence, lowers the cost of collecting information. We term this cost the access cost. Second, BI_t^{ϕ} refers to the cost of filtering the information, which increases with the degree of informatization. We can interpret this cost as a measure of the time taken to filter out the required information. That is, the more sources of information there are, the longer it takes to find the information source that has the required information. Moreover, as the number of information sources increases, it is harder to decide what is true and what is false.[6] A recent survey by the University of California at Berkley reported that, globally, about two exabytes (a billion gigabytes, or 10^{18} bytes) of information is produced annually; this amounts to about 250 megabytes per person. Arguably, such an excess of information makes it difficult to filter the necessary information. Therefore, informatization increases the cost of filtering information. We can interpret this as the effect of information overload. We term this the filtering cost.[7]

The information cost function has the following properties:

$$\frac{\partial IC(I_t, h_t^i)}{\partial h_t^i} < 0, \tag{4}$$

$$\frac{\partial IC(I_t, h_t^i)}{\partial I_t^i} = \begin{cases} < 0 \ \text{ if } I_t < \left(\frac{\psi A}{\phi B}\right)^{\frac{1}{\psi+\phi}} \\ \geq 0 \ \text{ if } I_t \geq \left(\frac{\psi A}{\phi B}\right)^{\frac{1}{\psi+\phi}} \end{cases}. \tag{5}$$

First, Eq. 4 shows that, when the degree of informatization is fixed, an increase in human capital, h_t^i, reduces the information cost. This means that voters who have more human capital are better able to collect information. For example, voters with higher human capital are more skilled in using personal computers (and so have a lower access cost) and in filtering out useful websites (and so have a lower filtering cost). Hence these voters collect information easily. Second, Eq. 5 means that, when the degree of informatization is low, an increase in the degree of informatization lowers the information cost. However, when the degree of informatization is too high, an increase in the degree of informatization raises the information cost (see Fig. 2).

[6] Jinwon and Tang [15] use five industry case studies to investigate the information overload problem and find that the quality of information is negatively related to informatization and information overload.

[7] Reis [30, 31] also claims that it is costly to acquire, absorb, and process information.

Figure 2 illustrates a U-shaped relationship between the degree of informatization and the information cost. When I_t is low, an increase in I_t lowers the information cost. This is so because the decrease in the access cost dominates the increase in the filtering cost. Suppose that there are no newspapers, television, or the Internet. Then, the diffusion of newspapers would reduce the access cost considerably. However, when the degree of informatization is low, the increase in the filtering cost is not excessive. Therefore, a decrease in the access cost dominates an increase in the filtering cost and, hence, the information cost decreases. By contrast, when I_t is excessively high, an increase in I_t increases the information cost. This is because the increase in the filtering cost outweighs the decrease in the access cost. For example, although the Internet has lowered access costs, it also generates excess information and considerably increases the filtering cost (through information overload).

The information cost is the key variable in our model. Most existing studies of the endogenous determination of policy implicitly assume that all voters have perfect information and that the cost of collecting information is zero. In this paper, we introduce the information cost explicitly. As we go on to show, this cost induces voter abstention and plays a key to role in explaining the 'new paradox of voting'.

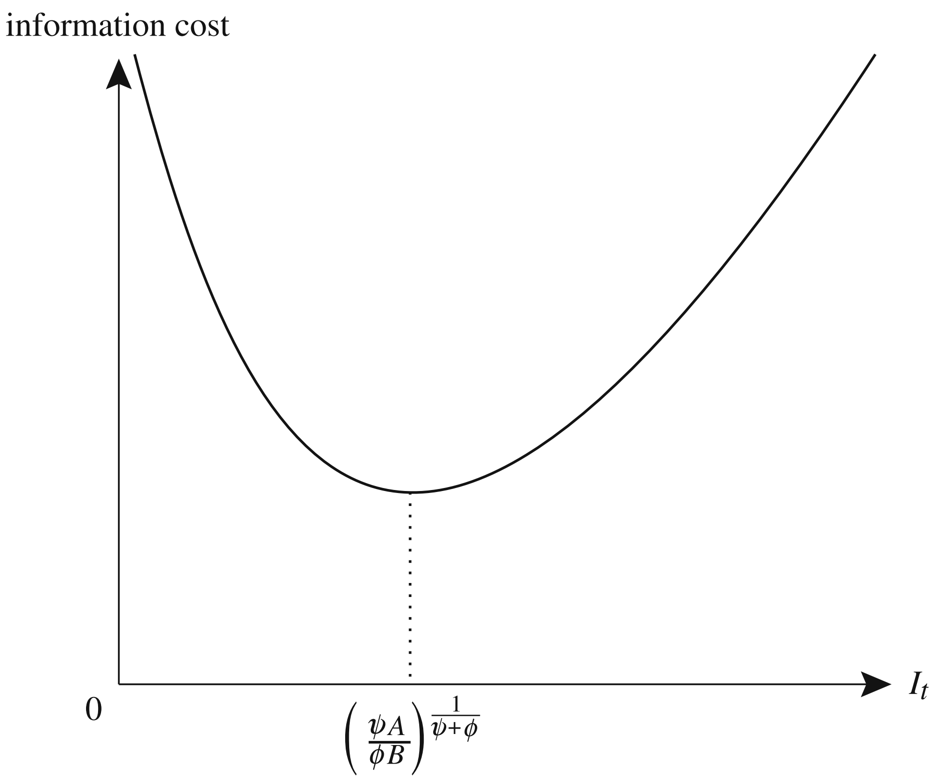

Fig. 2 The information cost

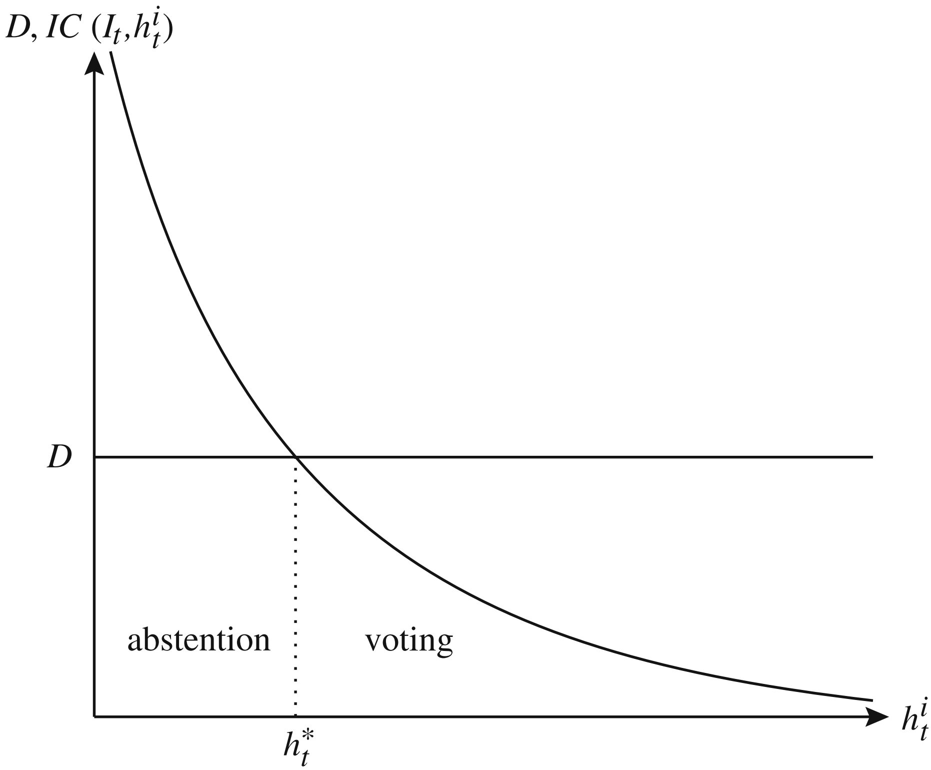

Fig. 3 The citizen duty and information cost

2.3 Voting-abstention choice

We assume that voters vote when the utility of voting, D, is higher than the information cost, $IC(I_t, h_t^i)$, and abstain from voting otherwise. Note that we may interpret abstention behavior under this assumption as Downs's "rational ignorance". Voters choose to abstain because the information cost is sufficiently high. They make a rational choice to be ignorant of politics and abstain from voting.

Hence, $IC(I_t, \cdot)$ is continuous, monotonically decreasing in h_t^i, and $\lim_{h_t^i \to 0} IC(I_t, h_t^i) = +\infty$, $\lim_{h_t^i \to +\infty} IC(I_t, h_t^i) = 0$ by Eq. 3. Thus, there must exist an h_t^* such that:

$$h_t^* = \left[\frac{\chi \left\{ A I_t^{-\psi} + B I_t^{\phi} \right\}}{D} \right]^{\frac{1}{\zeta}}, \qquad \text{where} \quad \begin{cases} h_t^i \geq h_t^* \Rightarrow \text{voting,} \\ h_t^i < h_t^* \Rightarrow \text{abstention.} \end{cases} \tag{6}$$

Figure 3 illustrates the threshold level of human capital corresponding to the choice between voting and abstaining.[8] Figure 3 shows that our model is consistent

[8]We assume that when, $D = IC(I_t, h_t^i)$, the electors choose to vote.

with existing theoretical and experimental studies: our model shows that voters with low income, low human capital or limited information tend to abstain from voting (cross-sectional differences in voting behavior).

2.4 The median voter

In this subsection, we discuss the median voter, under the assumption that some voters abstain.[9] We assume that there is a continuum of agents, $i \in [0, 1]$, and that human capital is lognormally distributed: $\ln h_t^i \sim N(m_t, v_t^2)$, $m_t \in \mathbb{R}$, $v_t \in \mathbb{R}_+$,[10] where m_t and v_t^2 are the mean and variance of the log-human capital distribution at period t, respectively.[11]

By definition, when no one abstains, the median voter's human capital, h_t^{med}, is determined as $\Pr(\ln h_t^i \leq \ln h_t^{med}) = (1/2) = \Omega(0)$, where $\Omega(\cdot)$ is the cumulative distribution function of a standard normal distribution. Because $\Pr(h_t^i \leq h_t^{med}) = \Omega\left((\ln h_t^{med} - m_t)/v_t\right)$, if no one abstains, the median voter's human capital is $\ln h_t^{med} = m_t$. However, if some do abstain, we must identify the median voter among electors who actually vote. As already mentioned, agents with less human capital than h_t^* abstain from voting; hence, the larger is the number of voters who abstain, the higher is the median voter's human capital (see Fig. 4).

When some voters abstain, the median voter's human capital is h_t^{med}, which must satisfy $\Pr(h_t^i \leq h_t^{med} \middle| h_t^i \geq h_t^*) = (1/2)$. By using a standard normalization, we can redefine the median voter and rewrite voter turnout as:

$$\Omega\left(\frac{\ln h_t^{med} - m_t}{v_t}\right) = \frac{1}{2} + \frac{1}{2} \cdot \Omega\left(\frac{\ln h_t^* - m_t}{v_t}\right), \tag{7}$$

$$\text{The voter turnout} = 1 - \Omega\left(\frac{\ln h_t^* - m_t}{v_t}\right). \tag{8}$$

Given that $\Omega\left((\ln h_t^* - m_t)/v_t\right) \geq 0$, the left-hand side of Eq. 7 must satisfy $\Omega((\ln h_t^{med} - m_t)/v_t) \geq (1/2)$. This property ensures that, if some abstain, the median voter's log-human capital exceeds the mean log-human capital, m_t. We define the following:

$$\Omega\left(\lambda\left(\frac{\ln h_t^* - m_t}{v_t}\right)\right) \equiv \frac{1}{2} + \frac{1}{2} \cdot \Omega\left(\frac{\ln h_t^* - m_t}{v_t}\right), \tag{9}$$

where $\lambda(\cdot) \in [0, +\infty)$ and $\lambda'(\cdot) \geq 0$. From this definition and from Eq. 7, we can represent the median voter's log-human capital as:

$$\ln h_t^{med} = m_t + v_t \cdot \lambda\left(\frac{\ln h_t^* - m_t}{v_t}\right) \geq m_t. \tag{10}$$

We can now state the following proposition.

[9]The method used in this subsection is also applied in Benabou [3].

[10]The lognormal distribution is an appropriate representation of the empirical data on income and human capital [3]. In addition, the lognormal approach facilitates dynamic analysis of income inequality.

[11]Note that m_t is the mean of log-human capital; hence, it lies between $-\infty$ and $+\infty$.

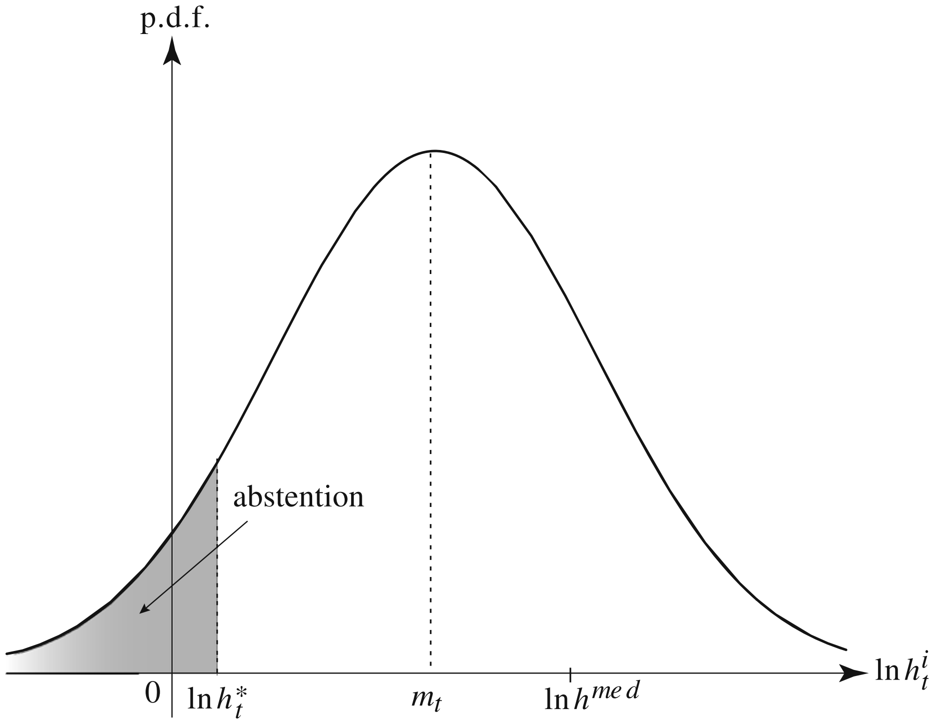

Fig. 4 Abstention

Proposition 1 *When $I_t < (\psi A/\phi B)^{\frac{1}{\psi+\phi}}$, an increase in the degree of informatization raises voter turnout and makes an individual with less human capital become the median voter. When $I_t > (\psi A/\phi B)^{\frac{1}{\psi+\phi}}$, an increase in the degree of informatization lowers voter turnout and makes an individual with more human capital become the median voter.*

Proof See Appendix A. □

This proposition is one of the main results of this paper. It tells us that informatization has positive and negative effects on voter turnout. When the degree of informatization is low, informatization reduces the information cost and raises voter turnout. However, when the degree of informatization is high, informatization raises the information cost and lowers voter turnout (through information overload). Consequently, there is an inverse U-shaped relationship between voter turnout and the degree of informatization.

Some empirical studies support this result. For example, using panel data on US counties during the period in which radio expanded (from 1920 to 1930), Strömberg [33] presents evidence that the penetration of radio increased voter turnout. In the context of our model, this development could be represented by the case where $I_t < (\psi A/\phi B)^{\frac{1}{\psi+\phi}}$. By contrast, using panel data on US cities from 1940 to 1970, Gentzkow [12] shows that the introduction of television significantly reduced voter turnout. In our model, this corresponds to the case where $I_t > (\psi A/\phi B)^{\frac{1}{\psi+\phi}}$.

Note that, as we explain in Section 4 below, the policy preferred by the median voter is implemented in the politico-economic equilibrium. Therefore, an increase in the median voter's human capital means that the implemented policy becomes more desirable for agents with higher human capital.

2.5 Advancement of informatization

We specify the advancement of informatization as:

$$I_t = \sigma \cdot \exp(m_t), \tag{11}$$

where $\sigma > 0$.[12,13] Equation 11 means that the degree of informatization, I_t, is determined by average human capital. We can then interpret I_t as externalities associated with human capital. For example, we may consider that an increase in average human capital reflects an increase in the literacy rate. An increase in the literacy rate increases the degree of informatization by making it easier for agents to exchange information through newspapers, books, magazines, for example. We may also explain this externality as a residual product of knowledge spillovers. When average human capital increases, the knowledge and skills of each agent spread to other agents. Then, in the process of spilling over, knowledge and skills are translated into information in the form of articles, books, videos and so on, which promote informatization.

Substituting Eq. 11 into Eq. 6, we can rewrite the threshold human capital, h_t^*, as:

$$\ln h_t^* = \Xi + g(m_t), \tag{12}$$

where $\Xi \equiv (1/\zeta) \cdot \ln(\chi/D)$ and $g(m_t) \equiv (1/\zeta) \cdot \ln\left[A\sigma^{-\psi}\exp(-\psi m_t) + B\sigma^{\phi}\exp(\phi m_t)\right]$. By definition, the first derivative of $g(m_t)$ is given by:

$$g'(m_t) = \frac{-\psi A\sigma^{-\psi}\exp(-\psi m_t) + \phi B\sigma^{\phi}\exp(\phi m_t)}{\zeta\left\{A\sigma^{-\psi}\exp(-\psi m_t) + B\sigma^{\phi}\exp(\phi m_t)\right\}} \begin{cases} < 0, & \text{if } m_t < \frac{1}{\psi+\phi}\ln\left(\frac{\psi A}{\phi B\sigma^{\psi+\phi}}\right) \\ \geq 0, & \text{if } m_t \geq \frac{1}{\psi+\phi}\ln\left(\frac{\psi A}{\phi B\sigma^{\psi+\phi}}\right) \end{cases}. \tag{13}$$

Therefore, $\ln h_t^*$ is also U-shaped with respect to m_t. Equation 13 indicates the following. When average human capital is low, the degree of informatization is also low. Hence, an increase in the average of log-human capital, m_t, lowers the information cost and increases the threshold, $\ln h_t^*$, by increasing in the degree of informatization, and vice versa. This explains the inverse U-shaped relationship between voter turnout and average log-human capital, or GDP.

We can now state the following proposition.

[12] We may interpret the degree of informatization as externalities of the average human capital, as Lucas [21] formulates.

[13] As long as I_t is increasing with m_t, the analysis that follows is not affected.

Proposition 2 *An increase in the mean of log-human capital, m_t, ceteris paribus, raises voter turnout when $m_t < (1/(\psi+\phi)) \cdot \ln\left[(\psi+\zeta)A/(\phi-\zeta)\sigma^{\psi+\phi}B\right]$, and vice versa. Moreover, an increase in the variance of log-human capital, v_t^2, ceteris paribus, raises* (*lowers*) *voter turnout when the voter turnout is over* (*under*) *50%.*

Proof See Appendix B. □

This proposition suggests a solution to the 'new paradox of voting'. When m_t (or GDP) is high enough, an increase in the mean of log-human capital, m_t, has a negative effect on voter turnout. This negative effect arises from the increase in the filtering cost (or from information overload). Excesssive informatization increases the filtering cost considerably. Consequently, the information cost becomes high for all voters, and voter turnout decreases. By contrast, an increase in the variance of log-human capital, v_t^2, has a negative (positive) effect when voter turnout is over (under) 50%. These results are summarized in Fig. 5.

Suppose that m_t is increasing with economic growth. Then, if the effect of an increase in m_t is high, relative to the effect of an increase in v_t^2, voter turnout has an inverse U-shaped relationship with m_t and economic growth. This means that voter turnout decreases with economic growth when the economy is sufficiently developed.

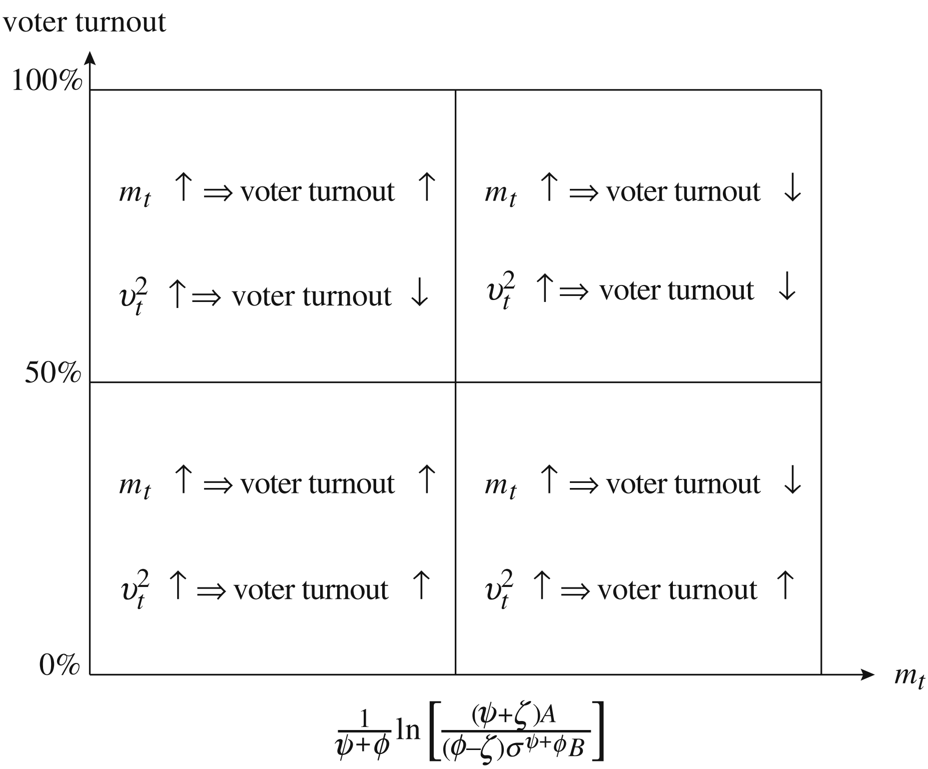

Fig. 5 The effect of increases in m_t and v_t^2

We have already shown that our model is consistent with existing theoretical and empirical studies. Thus, our model offers a solution to the 'new paradox of voting' and it can explain the cross-sectional and over-time differences in voting behavior simultaneously.[14]

Note that this model also predicts that voter turnout decreases because agents with low-income, low-human capital and limited information abstain from voting. Cavanagh [4] supports this prediction. Cavanagh [4] shows that the decrease in voter turnout from 1964 to 1976 in the US was disproportionately among the poorest and least informed groups of citizens: the steepest drops in voter turnout have been recorded among the poor and the least educated citizens.

Finally, note that from Eq. 10 the median voter's human capital is given by:

$$\ln h_t^{med} = m_t + v_t \cdot \lambda \left(\frac{\Xi + g(m_t) - m_t}{v_t} \right). \tag{14}$$

In this section, we have discussed the formulation of a model of the choice between voting and abstaining and the determination of the identity of the median voter when some abstain. Moreover, we have shown that informatization and information overload are the keys to solving the 'new paradox of voting'. In the rest of this paper, we discuss the relationships between the dynamics of the income distribution, the effect of informatization, and long-run decline in voter turnout.

3 The economic model

In this section, we discuss the second part of the model; that is, the economic model. We set up a neoclassical dynamic macroeconomic model, which has also been used in Benabou [3] and Takii and Tanaka [34]. We describe the dynamic relationship between redistribution policy and the distribution of human capital.

The economy is populated by nonoverlapping generations of families, $i \in [0, 1]$, and there is no population growth. We assume that the initial distribution of human capital between families is $\ln h_0^i \sim N(m_0, v_0^2)$. The sequence of events is as follows. Each agent's human capital is determined by their parents' investment in education. Agents choose between voting and abstaining. The equilibrium tax rate in period t is determined on the basis of pure majority voting. Agents learn the value of their idiosyncratic productivity shocks, z_t^i and η_t^i. Agents produce goods by using their human capital. Gross income and disposable income are thus determined. Agents then allocate their disposable incomes between their own consumption and education investment for their children. Then, their offspring's human capital is determined.

[14] Note that this model does not claim that the cross-country association between GDP and voter turnout is inverse U-shaped. Determining factors in the voter turnout are not only the level of GDP but also other economic and political factors. For example, distribution of human capital, advancement of informatization, citizen's preference for policies (these are represented by the parameters in this model) also affect to the voter turnout. Therefore, countries with similar levels of GDPs may have different rates of voter turnout.

Agent i of generation t produces output by use of his or her human capital, h_t^i, subject to an independently and identically distributed idiosyncratic productivity shock, z_t^i :

$$y_t^i = z_t^i (h_t^i)^{\gamma}, \tag{15}$$

where y_t^i is gross income and $\gamma \in (0, 1)$ is a parameter. In this economy, agents have preferences defined over their own consumption, c_t^i, and their offspring's human capital, h_{t+1}^i (which represents altruism). The taxes and transfers specified below transform gross income, y_t^i, into disposable income, $\hat{y}_t^i$. Agents allocate this disposable income to their own consumption, c_t^i, and to education investment for their offspring, e_t^i. For simplicity, we assume that their offspring's human capital is determined solely by education investment and the idiosyncratic shocks, η_t^i. This assumption means that children cannot inherit human capital from their parents. We specify the production function of human capital as:

$$h_{t+1}^i = \kappa \eta_t^i (e_t^i)^{\beta}, \tag{16}$$

where $\kappa > 0$ and $\beta \in (0, 1)$ are parameters, and η_t^i is an independently and identically distributed idiosyncratic productivity shock. As argued above, both shocks, z_t^i and η_t^i, are unknown when people vote. Hence, redistribution policy acts as a hedge against risk.[15] For simplicity, both shocks are assumed to be lognormally distributed: $\ln z_t^i \sim N(-r^2/2, r^2)$ and $\ln \eta_t^i \sim N(-q^2/2, q^2)$, $r, q > 0$.

Taxes and transfers transform agent i's gross income, y_t^i, into disposable income, $\hat{y}_t^i$, as follows:

$$\hat{y}_t^i = \left(y_t^i\right)^{1-\tau_t} (\tilde{y}_t)^{\tau_t} = c_t^i + e_t^i, \tag{17}$$

where $\tau_t \in [0, 1]$ is the tax rate in period t, and $\tilde{y}_t$ is the break-even level of income. Therefore, agents with gross incomes exceeding $\tilde{y}_t$ pay tax, and those with gross incomes lower than $\tilde{y}_t$ receive subsidies. Note that, under this scheme, the ratio of tax payments (or subsidies) to gross income is $(y_t^i - \hat{y}_t^i)/y_t^i = 1 - \left(\tilde{y}_t / y_t^i\right)^{\tau_t}$. Thus, there is a progressive taxation system.[16] Equation 17 implies that, when $\tau_t = 1$, all agents have the same disposable income. The break-even level of income, $\tilde{y}_t$, is determined by the government's budget constraint, under which the sum of net transfers must be zero:

$$\int_0^1 \left(y_t^i\right)^{1-\tau_t} (\tilde{y}_t)^{\tau_t} di = y_t, \tag{18}$$

where y_t is average income in period t: $y_t = \mathbb{E}[y_t^i]$.

We specify $u(c_t^i, h_{t+1}^i | \tau_t)$ in Eq. 1 as:

$$u\left(c_t^i, h_{t+1}^i \middle| \tau_t\right) = (1 - \rho) \ln c_t^i + \rho \ln h_{t+1}^i. \tag{19}$$

[15] Both productivity shocks, z_t^i and η_t^i, also ensure that the variance of log-human capital, v^2, is strictly positive.

[16] See Benabou [3] for details of this policy scheme.

where $\rho \in (0, 1)$ defines the relative weights assigned to agents' felicity and altruistic motives. We assume that $u(c_t^i, h_{t+1}^i \big| \tau_t)$ is the utility function in the remainder of this paper.[17]

Proposition 3 *Given the tax rate τ_t, agents choose a common saving rate ξ:*

$$e_t^i = \xi \hat{y}_t^i, \quad c_t^i = (1 - \xi)\hat{y}_t^i, \tag{20}$$

where $\xi \equiv \rho\beta/(1 - \rho + \rho\beta) \in (0, 1)$.

Proof See Appendix C. □

We discuss the dynamics of human capital distribution and of GDP. Using Proposition 3, and given Eqs. 15 to 18, and given the properties of the lognormal distribution, $\mathbb{E}[z_t^i] = 1$, and given that $\mathbb{E}[(h_t^i)^\gamma] = \exp\left(\gamma m_t + \gamma^2 v_t^2/2\right)$ (see Appendix D), it follows that human capital accumulation is simply determined by:

$$\begin{aligned} \ln h_{t+1}^i &= \ln \eta_t^i + \ln(\kappa \xi^\beta) + \beta(1 - \tau_t) \ln z_t^i + \beta\gamma(1 - \tau_t) \ln h_t^i \\ &\quad + \beta\gamma\tau_t m_t + \beta \cdot \frac{\gamma^2 v_t^2}{2} \cdot \tau_t(2 - \tau_t) + \frac{\beta r^2}{2} \cdot \left\{(1 - \tau_t) - (1 - \tau_t)^2\right\}. \end{aligned} \tag{21}$$

Taking expectations and the variances of both sides of Eq. 21, we obtain the following difference equations, which govern the evolution of the economy:

$$m_{t+1} = -\frac{q^2}{2} + \ln\left(\kappa \xi^\beta\right) + \tau_t(2 - \tau_t) \cdot \frac{\beta\gamma^2 v_t^2}{2} - (1 - \tau_t)^2 \cdot \frac{\beta r^2}{2} + \beta\gamma m_t, \tag{22}$$

$$v_{t+1}^2 = q^2 + \beta^2(1 - \tau_t)^2 r^2 + \beta^2\gamma^2(1 - \tau_t)^2 v_t^2. \tag{23}$$

The effect of income redistribution on the dynamics of human capital (or income) inequality is clear: the tax rate, τ_t, determines the persistence of family wealth inequality, $\beta^2\gamma^2(1 - \tau_t)^2$. Given Eq. 22 and 23, when the sequence of tax rates, $\{\tau_t\}_{t=0}^\infty$, is determined, the dynamics of the mean and variance of log-human capital follow simple first-order difference equations. Moreover, from Eq. 23, it follows that the productivity shocks, z_t^i and η_t^i, affect the dynamics of the variance of log-human capital; that is, the dynamics of income inequality. This means that productivity shocks increase income inequality.

Now consider the GDP growth rate. We have assumed that the economy is populated by nonoverlapping generations of families, $i \in [0, 1]$; hence, average income can be interpreted as GDP. From Eq. 18, average income, y_t, is:

$$\ln y_t = \gamma m_t + \frac{\gamma^2 v_t^2}{2}.$$

[17]Note that, given Eq. 1, utility from voting, $V(I_t, h_t^i)$, and utility from non-taxation policies, $W(\mathbf{Z}_t)$, do not affect the optimization of c_t^i and e_t^i.

Both m_t and v_t^2 positively affect $\ln y_t$, despite the concavity of the production function.[18] Now,we define the GDP growth rate as $\ln(y_{t+1}/y_t)$. Then, using Eqs. 22 and 23, we obtain:

$$\ln\left(\frac{y_{t+1}}{y_t}\right) = -(1-\beta\gamma)\ln y_t + \frac{q^2}{2}\gamma(\gamma-1) + \gamma\ln(\kappa\xi^\beta) - \Theta_t \cdot \left(\frac{\gamma^2 v_t^2 + r^2}{2}\right),$$

where $\Theta_t \equiv \beta\gamma(1-\tau_t)^2(1-\beta\gamma) \geq 0$. The first term on the right-hand side, $-(1-\beta\gamma)\ln y_t$, represents a standard convergence effect. Because we have assumed that $\beta \in (0,1)$ and $\gamma \in (0,1)$, this term decreases as the $\ln y_t$ increases.[19] The term $-\Theta_t \cdot \left((\gamma^2 v_t^2 + r^2)/2\right)$ represents the effect of the variance of log-human capital and the effect of the productivity shock, z_t^i. Because $\Theta_t \geq 0$, increases in the variance of human capital and variance of productivity shock lower GDP growth. The reason for this is simple. Given that the saving rate is the same for all agents and given that there are diminishing returns to education investment, an increase in the variance of human capital lowers average human capital and the income of the next generation. In addition, because Θ_t is a decreasing function of τ_t, we can state next proposition.

Proposition 4 *In this economy, the tax rate that maximizes the GDP growth rate in period t is $\tau_t = 1$.*

This result is consistent with that of Alesina and Rodrik [2].[20]

In this section, we have discussed the dynamics of log-human capital distribution and of GDP growth. We found that $\tau_t = 1$ maximizes GDP growth in period t. However, in this economy, the tax rate is determined not by the government but by the pure majority voting. In the next section, we discuss the equilibrium tax rate that is determined on the basis of the pure majority voting and investigate the steady state of economy.

4 Politico-economic equilibrium

In this section, combining the voting model and the economic model discussed above, we derive a politico-economic equilibrium. Moreover, we analyze the dynamics of voter turnout, the equilibrium policies determined on the basis of the pure majority voting, and changes in income inequality and GDP. We also discuss the social costs of a fall in voter turnout in terms of the associated negative effects on GDP growth.

[18] This feature depends on the assumption of a log-normal distribution. When $\ln h_t^i$ is normally distributed, h_t^i has a right-skewed distribution function. This means that the mean of h_t^i increases with the variance of $\ln h_t^i$. Hence, an increase in the variance of $\ln h_t^i$ has a positive effect on GDP.

[19] If $\beta\gamma > 1$, this term increases with the growth rate, in which case, there is a possibility of endogenous growth.

[20] When $\beta\gamma > 1$, the tax rate that maximizes the GDP growth rate in period t is $\tau_t = 0$. This result is consistent with that of Li and Zou [18].

Given Eq. 19 and Proposition 3, agent i's expected utility before voting under a given tax rate, τ_t, is given by:[21]

$$\begin{aligned}\mathbb{E}\left[u\left(c_t^i, h_{t+1}^i \middle| \tau_t\right)\right] = &\ln\left[(1-\xi)^{1-\rho}\xi^{\rho\beta}\right] + (1-\rho+\rho\beta)(1-\tau_t)\gamma\ln h_t^i \\ &-(1-\rho+\rho\beta)(1-\tau_t)\cdot\frac{r^2}{2} - \rho\cdot\frac{q^2}{2} + \rho\ln\kappa + \tau_t(1-\rho+\rho\beta)\gamma m_t \\ &+\tau_t(2-\tau_t)(1-\rho+\rho\beta)\cdot\frac{\gamma^2 v_t^2}{2} - \tau_t(\tau_t-1)(1-\rho+\rho\beta)\cdot\frac{r^2}{2}.\end{aligned} \tag{24}$$

Given Eq. 24, the optimal tax rate for agent i who has human capital of h_t^i is:

$$\left(\tau_t^i\right)^* = \begin{cases} 1 & \text{if } \ln h_t^i \le m_t, \\ 1 - \dfrac{\gamma\left(\ln h_t^i - m_t\right)}{\gamma^2 v_t^2 + r^2} & \text{if } m_t < \ln h_t^i < m_t + \dfrac{\gamma^2 v_t^2 + r^2}{\gamma}, \\ 0 & \text{if } m_t + \dfrac{\gamma^2 v_t^2 + r^2}{\gamma} \le \ln h_t^i, \end{cases} \tag{25}$$

where $(\tau_t^i)^*$ is the optimal tax rate for agent i in period t, and Eq. 25 must satisfy $(\tau_t^i)^* \in [0, 1]$ for $\forall h_t^i \ge 0$. An increase in the variance of the productivity shock, r^2, or an increase in the variance of human capital, v_t^2, increases the optimal tax rate, $(\tau_t^i)^*$. This is because the higher are these factors, the greater is risk, in which case, people prefer greater redistribution for more of a hedge against risk. Moreover, an increase in human capital, $\ln h_t^i$, lowers the optimal tax rate, $(\tau_t^i)^*$. This is because the taxation system is progressive .

As argued in Section 2, when some voters abstain, the median voter's human capital is $\ln h_t^{med} = m_t + v_t \cdot \lambda\left((\Xi + g(m_t) - m_t)/v_t\right)$. Therefore, by substituting Eq. 14 into Eq. 25, we obtain the tax rate that is preferred by the median voter, τ_t^{med}, which is:

$$\tau_t^{med} = \max\left\{1 - \frac{\gamma\left(\ln h_t^{med} - m_t\right)}{\gamma^2 v_t^2 + r^2},\ 0\right\} = \max\left\{1 - \frac{\gamma v_t \cdot \lambda\left(\frac{\Xi + g(m_t) - m_t}{v_t}\right)}{\gamma^2 v_t^2 + r^2},\ 0\right\}. \tag{26}$$

We can now state the next proposition.

Proposition 5 *A fall in voter turnout lowers the GDP growth rate.*

Proof Given Eqs. 8 and 12, voter turnout is $1 - \Omega\left((\ln h_t^* - m_t)/v_t\right) = 1 - \Omega\left((\Xi + g(m_t) - m_t)/v_t\right)$. Then, given equation Eqs. 9 and 10, a fall in voter turnout increases the median voter's human capital. From Eq. 26, it follows that:

$$\frac{\partial \tau_t^{med}}{\partial \ln h_t^{med}} < 0.$$

[21] Note that we assumed that the productivity shocks, z_t^i and η_t^i, are unknown when agents vote.

Hence, a fall in voter turnout in period t lowers the equilibrium tax rate and lowers the degree of income redistribution in period t. From Proposition 4, it follows that the GDP growth rate in period t is maximized when $\tau_t = 1$. Hence a decrease in voter turnout in period t lowers the GDP growth rate in period t. □

Proposition 5 reveals that a short-run social cost is associated with a fall in voter turnout. This result is very intuitive. When agents with less human capital (income) have a greater tendency to abstain from voting than agents with more human capital (income), the lower voter turnout makes the equilibrium tax rate determined on the basis of the pure majority voting more favorable to those with a higher level of human capital (income). Hence, under a progressive taxation system, a fall in voter turnout increases income inequality by promoting a lower degree of income redistribution. Moreover, if the human capital production function exhibits decreasing returns, the GDP growth rate in period t declines. This prediction is supported by some empirical studies. For example, using cross-national data set spans from 1960 to 1990 on "strong democratic"[22] countries, Mueller and Stratmann [24] show that citizen participation increases government size or transfers, and these in turn reduce income inequality. Moreover, using cross-national data set spans from 1960 to 1990 on democratic countries, they show that a fall in voter turnout lowers the GDP growth rate.

Next, we characterize the steady state.

Proposition 6 *The policy that is preferred by the median voter,* $\boldsymbol{P}_t^{med} = (\tau_t^{med}, \boldsymbol{Z}_t^{med})$, *is the equilibrium policy in period t* $\forall t$.

Proof See Appendix E. □

According to the median voter theorem, the equilibrium tax rate determined on the basis of the pure majority voting is τ_t^{med}. Hence, from Eqs. 22 and 23, the dynamic behavior of the economy is represented by:

$$m_{t+1} = -\frac{q^2}{2} + \ln(\kappa\xi^{\beta}) + \tau_t^{med}(2 - \tau_t^{med}) \cdot \frac{\beta\gamma^2 v_t^2}{2} - (1 - \tau_t^{med})^2 \cdot \frac{\beta r^2}{2} + \beta\gamma m_t, \quad (27)$$

$$v_{t+1}^2 = q^2 + \beta^2(1 - \tau_t^{med})^2 r^2 + \beta^2\gamma^2(1 - \tau_t^{med})^2 v_t^2. \quad (28)$$

Given Eq. 26, the equilibrium tax rate that is preferred by the median voter depends only on m_t and v_t^2. Hence, by substituting Eq. 26 into Eqs. 27 and 28, we can rewrite these equations as first-order nonlinear difference equations in m_t and v_t^2.

In this section, we have discussed the politico-economic equilibrium. In the next section, we use a numerical example to demonstrate the features of the transition path and the steady state of this economy.

5 Numerical example

In Sections 2 and 3, we described the voting model and the economic model. In Section 4, we combined both models and derived the politico-economic equilibrium.

[22] The "Strong democratic" category contains the US, EU members, Canada and so on.

We also described the system that determines the long-run transition path of the economy. It is worth illustrating the transition path by using a numerical example to explaining the relationships between the variables.

Figure 6 displays the phase diagram of the system described by Eqs. 26 to 28 with $\chi = 0.07,\ A = 1,\ B = 2,\ \zeta = 0.5\ \psi = 0.3,\ \phi = 2,\ D = 0.2,\ \sigma = 1,\ \gamma = 0.6,\ \beta = 0.8,$ $\kappa = 1.5, q = 1.5, r = 0.1, \rho = 0.7$.

In this figure, the solid line depicts the $dm_t = 0$ locus and the dashed line depicts the $dv_t^2 = 0$ locus. Note that, from Eqs. 26, 27 and 28, the $dm_t = 0$ locus and the $dv_t^2 = 0$ locus are dominated on the basis that either $\tau_t^{med} > 0$ or $\tau_t^{med} = 0$. The dotted line depicts the $\tau_t^{med} = 0$ locus. Above the $\tau_t^{med} = 0$ locus, the $dm_t = 0$ locus and the $dv_t^2 = 0$ locus are based on $\tau_t^{med} > 0$; below the $\tau_t^{med} = 0$ locus, the $dm_t = 0$ locus and the $dv_t^2 = 0$ locus are based on $\tau_t^{med} = 0$. Given Eqs. 27 and 28, the $dm_t = 0$ locus and the $dv_t^2 = 0$ locus can be rewritten as:

$$m_t = \frac{1}{1-\beta\gamma} \cdot \left\{ -\frac{q^2}{2} + \ln(\kappa\xi^{\beta}) - \frac{\beta r^2}{2} \right\}, \qquad v_t^2 = \frac{q^2 + \beta^2 r^2}{1 - \beta^2\gamma^2},$$

when $\tau_t^{med} = 0$. Below the $\tau_t^{med} = 0$ locus, the $dm_t = 0$ locus is a vertical line and the $dv_t^2 = 0$ locus is a horizontal line. In Fig. 6, the steady-state tax rate is zero.

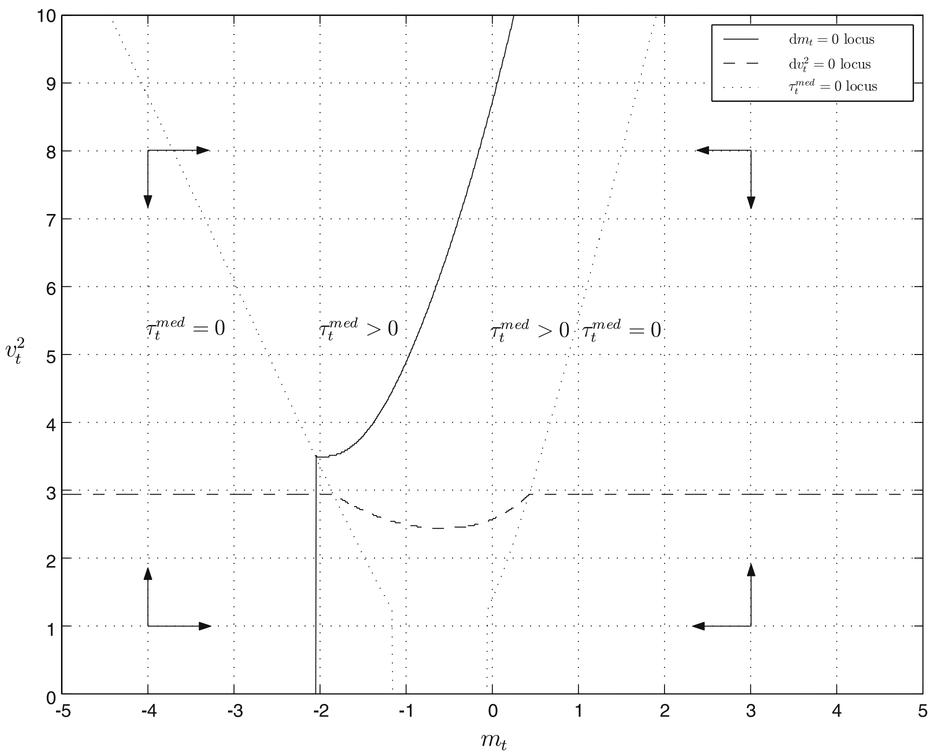

Fig. 6 Phase diagram based on $\chi = 0.07,\ A = 1,\ B = 2,\ \zeta = 0.5\ \psi = 0.3,\ \phi = 2,\ D = 0.2,\ \sigma = 1,$ $\gamma = 0.6, \beta = 0.8, \kappa = 1.5, q = 1.5, r = 0.1$ and $\rho = 0.7$

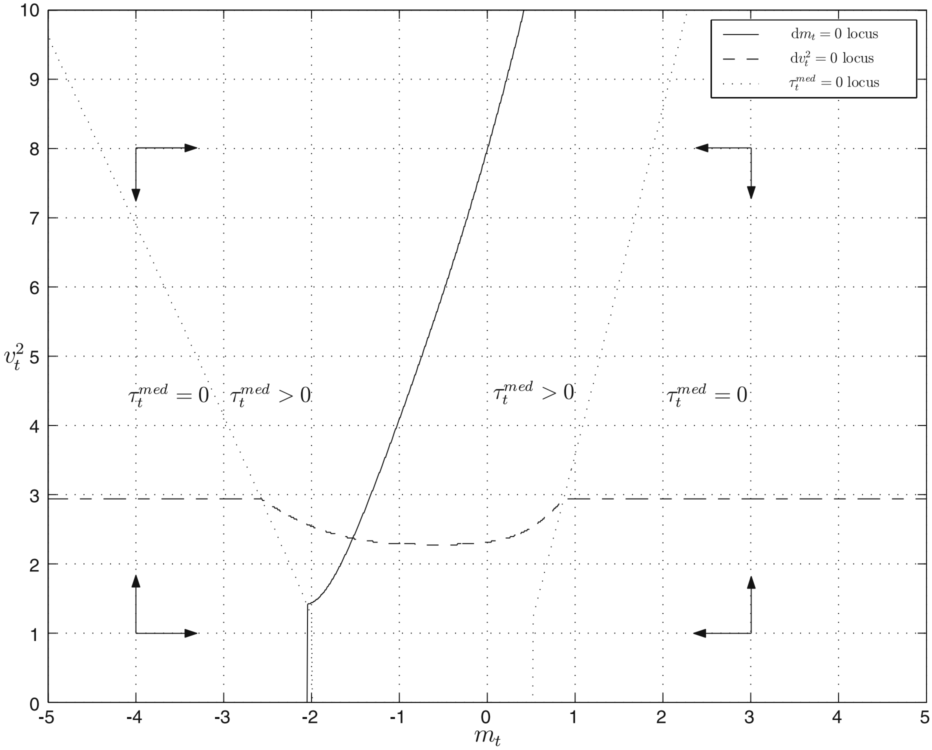

Fig. 7 Phase diagram based on $\chi = 0.04$, $A = 1$, $B = 2$, $\zeta = 0.5$ $\psi = 0.3$, $\phi = 2$, $D = 0.2$, $\sigma = 1$, $\gamma = 0.6$, $\beta = 0.8$, $\kappa = 1.5$, $q = 1.5$, $r = 0.1$ and $\rho = 0.7$

Figure 7 displays the phase diagram based on $\chi = 0.04$ with the other parameters taking the same value as in Fig. 6.

Given Eq. 3, a lower χ implies a lower information cost. From Figs. 6 and 7, it is apparent that a decrease in χ lowers the kink point of the $dm_t = 0$ locus. In comparison with Fig. 6, the steady state shifts lower and to the right, which implies an increase in GDP and fall in income inequality. Intuitively, a lower χ (that is, a lower information cost) increases voter turnout and raises tax rate. A rise in the tax rate reduces the degree of income inequality by increasing the degree of income redistribution. Moreover, as shown in Proposition 4, the rise in the tax rate also raises GDP.

Now we consider the transition path. Figure 8 displays the transition path in the case of $\chi = 0.01$, $A = 1$, $B = 2$, $\zeta = 0.5$ $\psi = 0.3$, $\phi = 2$, $D = 0.2$, $\sigma = 12$, $\gamma = 0.6$, $\beta = 0.8$, $\kappa = 1.5$, $q = 1.5$, $r = 0.1$ and $\rho = 0.7$. This parameter set generates plausible sequences for voter turnout and GDP.

In this case, voter turnout exhibits an inverse U-shape. From Proposition 2, when $m_t < (1/(\psi + \phi)) \cdot \ln\left[(\psi + \zeta)A/(\phi - \zeta)\sigma^{\psi+\phi}B\right]$, an increase in m_t raises voter turnout. When m_t and I_t are low, an increase in the degree of informatization lowers the access cost considerably, but the rise in the filtering cost is limited. Hence, the information cost, which is the sum of the access cost and filtering cost, decreases, and voter turnout increases. By contrast, when $m_t > (1/(\psi + \phi)) \cdot$

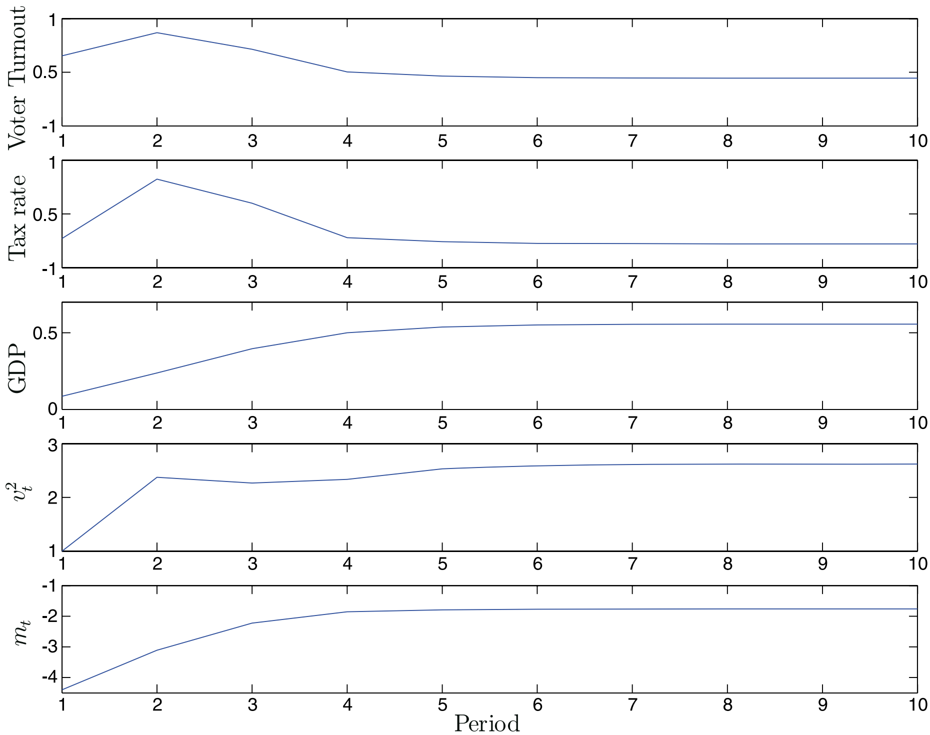

Fig. 8 Transition path of an economy based on $\chi = 0.01$, $A = 1$, $B = 2$, $\zeta = 0.5$ $\psi = 0.3$, $\phi = 2$, $D = 0.2$, $\sigma = 12$, $\gamma = 0.6$, $\beta = 0.8$, $\kappa = 1.5$, $q = 1.5$, $r = 0.1$ and $\rho = 0.7$

$\ln\left[(\psi + \zeta)A/(\phi - \zeta)\sigma^{\psi+\phi}B\right]$, an increase in m_t reduces voter turnout. When m_t and I_t are high, an increase in the degree of informatization raises the filtering cost considerably, but the decline in the access cost is small. Hence, the information cost rises, and voter turnout falls. In Fig. 8, the effect of the degree of informatization is different in period 2, and voter turnout is represented by an inverse U-shaped curve. Thus, our model explains the observed patterns described in the Introduction (see Fig. 1). Nardulli et al. [25] argue that voter turnout in the US is described by an inverse U-shaped curve; it increased from 1920 to 1960 and decreased form 1960 on. In this numerical example, period 2 corresponds to the 1960 in the US.[23]

Moreover, after period 2, voter turnout decreases as GDP, the average log-human capital and the degree of informatization increase.[24] In Section 2, we showed that

[23]Nardulli et al. [25] also argue that voter turnout in the US decreased from 1876 to 1920. Our model cannot describe such a decline. Two reasons may explain this inconsistency. First, the advancement of informatization was weak before the 1920s. For example, Strömberg [33] argues that radio expanded from 1920 to 1930 in the US. Thus we can interpret that full-scale informatization in the US began from 1920. Second, we have assumed that all agents are eligible to vote, but women in the US were not enfranchised until 1920. Therefore, the movement in voter turnout in the period from 1876 to 1920 in the US can be exempted from the analysis of this model.

[24]Recall that the degree of informatization, I_t, is determined by average human capital, m_t.

voters with low income, low human capital or limited information tend to abstain from voting. Therefore, this transition path shows that our model can explain the cross-sectional and over-time differences in voting behavior simultaneously, and provide a solution to the 'new paradox of voting'.

Figure 8 also illustrates the relationships between the variables. A decrease (increase) in voter turnout means that an agent with a higher (lower) level of human capital becomes the median voter (see Proposition 1). Given Eq. 26, an increase in voter turnout lowers (raises) the equilibrium tax rate determined on the basis of the pure majority voting. Consequently, a fall (rise) in the tax rate lowers (raises) the degree of income redistribution, and thereby increases (reduces) the variance of log-human capital, v_t^2, which implies an increase (a fall) in income inequality. Mueller and Stratmann [24] support this prediction. Using the cross-national data set spans from 1960 to 1990 on "strong democratic"[25] countries, Mueller and Stratmann [24] show that citizen participation raises the size of the government or transfers, which in turn reduces income inequality.

In this section, we have obtained two implications of our model by using numerical examples base on the analysis of previous sections. First, higher filtering cost (or information overload) could explain the dynamic decrease in voter turnout, and thus provide a solution to the 'new paradox of voting'. Second, a lower voter turnout generates social costs in the form of lower GDP and greater income inequality.

6 Conclusion

In this paper, we have proposed the 'new paradox of voting', which means that, from a static point of view, voters with low incomes, low human capital or limited information tend to abstain from voting (cross-sectional differences in voting behavior), however, from a dynamic point of view, voter turnout decreases with increases in average incomes, human capital and the degree of informatization (over-time differences in voting behavior). We have introduced the 'access cost' and the 'filtering cost' into a neoclassical macroeconomic model and offered a solution to the 'new paradox of voting'. That is, increasing informatization raises the filtering cost by generating information overload; then, the increase in the filtering cost lowers voter turnout. We have used an illustrative numerical example, and have shown that our model can explain the cross-sectional differences and the over-time differences in voting behavior simultaneously; it can offer a solution to the 'new paradox of voting'.

We have also discussed the social costs of a decrease in voter turnout. When the production functions for goods and human capital are both strictly concave, a higher tax rate at time t raises GDP growth at t. Then, the fall in voter turnout makes an individual with a higher level of human capital become the median voter, which reduces the tax rate through majority voting. Consequently, a fall in voter turnout lowers the GDP growth rate, hence raising social costs.

This model generates a policy implication. That is, a decrease in voter turnout generates social costs. Therefore, it would be desirable to halt the fall in voter turnout over time in developed countries. We also found that an increase in the filtering

[25] "Strong democratic" category contains the US, EU members, Canada and so on.

cost associated with greater informatization may be the cause of the continuing decline in voter turnout. However, it is difficult to control informatization and limit information overload. This suggests that halting the continuing decline in voter turnout by controlling informatization would be difficult. Therefore, perhaps voting should be compulsory, as is the case in, for example, Italy, Australia, Belgium and Singapore.[26]

Acknowledgements I am very grateful to Kazuo Mino for his invaluable help and encouragement. I acknowledge the technical support by Takeo Hori. I also thank anonymous referees and editors, Jacques Silber, Francisco H. G. Ferreira and Branko Milanovic, for very constructive comments and suggestions. I also acknowledge the helpful comments by Francisco Ferreira, Koichi Futagami, Ryo Horii, Nobuhiro Hosoe, Masako Ikefuji, Yutaka Imai, Kazuaki Kagami, Junji Kageyama, Philip Keefer, Branko Milanovic, Akira Momota, Yasutomo Murasawa, Ryoji Ohdoi, Hirotaka Ohmura, Tetsuo Ono, Makoto Saito, Kengo Soga, Hanako Takashima, Ryuichi Tanaka, Takuma Wakayama, Hideo Yunoue, and seminar participants at Osaka University, Osaka Prefecture University, Meikai University, III World Bank Conference on Inequality and PET 06 Hanoi. Any remaining errors are mine. Financial aid from the Japan Society for the Promotion of Science Research Fellowships for Young Scientists is gratefully acknowledged.

Appendix A: Proof of Proposition 1

Proof We start with the proof relating to voter turnout. From Eq. 8:

$$\frac{\partial}{\partial I_t}\left(1-\Omega\left(\frac{\ln h_t^*-m_t}{v_t}\right)\right)=-\frac{-\psi A I_t^{-\psi-1}+\phi B I_t^{\phi-1}}{\zeta\left\{A I_t^{-\psi}+B I_t^{\phi}\right\}}\cdot\frac{\partial}{\partial \ln h_t^*}\Omega\left(\frac{\ln h_t^*-m_t}{v_t}\right).$$

Since $\Omega(\cdot)$ is the standard normal distribution function, $(\partial/\partial \ln h_t^*)\Omega\left((\ln h_t^*-m_t)/v_t\right) > 0$. Therefore, when $I_t < (\psi A/\phi B)^{\frac{1}{\psi+\phi}}$, an increase in the degree of informatization, I_t, raises voter turnout, and vice versa. Moreover, by Eq. 10:

$$\frac{\partial \ln h_t^{med}}{\partial I_t}=v_t\cdot\frac{\partial}{\partial \ln h_t^*}\cdot\lambda\left(\frac{\ln h_t^*-m_t}{v_t}\right)\cdot\frac{-\psi A I_t^{-\psi-1}+\phi B I_t^{\phi-1}}{\zeta\left\{A I_t^{-\psi}+B I_t^{\phi}\right\}},$$

where $\lambda'(\cdot)>0$. Therefore, $(\partial \ln h_t^{med}/\partial I_t)<0$ when $I_t<(A\psi/B\phi)^{\frac{1}{\psi+\phi}}$, and vice versa. □

Appendix B: Proof of Proposition 2

Proof We can rewrite voter turnout as $1-\Omega\left((\ln h_t^*-m_t)/v_t\right)=1-\Omega\big((\Xi+g(m_t)-m_t)/v_t\big)$ by use of Eq. 12. Therefore:

$$\frac{\partial}{\partial m_t}\left\{1-\Omega\left(\frac{\Xi+g(m_t)-m_t}{v_t}\right)\right\}=\frac{1-g'(m_t)}{v_t}\cdot\Omega'\left(\frac{\Xi+g(m_t)-m_t}{v_t}\right).$$

[26] Using cross-country data from 91 countries for the period 1960–2000, Chong and Olivera [5] shows that compulsory voting, when enforced strictly, reduces income inequality, as measured by the Gini coefficient.

Note that $\Omega(\cdot)$ is a standard normal distribution function, and hence $\Omega'(\cdot) > 0$. Given the definition of $g(m_t)$, we obtain:

$$g'(m_t) < 1 \Leftrightarrow m_t < \frac{1}{\psi + \phi} \cdot \ln\left[\frac{(\psi + \zeta)A}{(\phi - \zeta)\sigma^{\psi+\phi}B}\right].$$

Hence, if $m_t < (1/(\psi + \phi)) \cdot \ln\left[(\psi + \zeta)A/(\phi - \zeta)\sigma^{\psi+\phi}B\right]$, an increase in the mean of log-human capital raises voter turnout; the opposite is also true. Moreover:

$$\frac{\partial}{\partial v_t^2}\left\{1 - \Omega\left(\frac{\Xi + g(m_t) - m_t}{v_t}\right)\right\} = \frac{\ln h_t^* - m_t}{2v_t^3} \cdot \Omega'\left(\frac{\Xi + g(m_t) - m_t}{v_t}\right).$$

Therefore, if $\ln h_t^* < m_t$ (that is, if voter turnout is over 50%), an increase in the variance of log-human capital lowers voter turnout, and vice versa. □

Appendix C: Proof of Proposition 3

Proof Let us define $\omega_t^i \equiv (e_t^i/\hat{y}_t^i)$. Then, given Eqs. 15, 16, 17 and 19, we obtain:

$$u\left(c_t^i, h_{t+1}^i \middle| \tau_t\right) = (1 - \rho)\left[\ln\left(1 - \omega_t^i\right) + \tau_t \ln \tilde{y}_t + (1 - \tau_t)\left[\ln z_t^i + \gamma \ln h_t^i\right]\right] \\ + \rho\left[\ln \kappa + \ln \eta_t^i + \beta\left\{\ln \omega_t^i + (1 - \tau_t)\left[\ln z_t^i + \gamma \ln h_t^i\right] + \tau_t \ln \tilde{y}_t\right\}\right]. \tag{29}$$

Given Eq. 29, we obtain Eq. 20. □

Appendix D: Properties of the lognormal distribution

First, let us assume that $\ln x \sim N(\mu, \sigma^2)$ and $G(x)$ is cumulative distribution function of x. Then, by definition, it follows that:

$$G(w) = \Pr(x \leq w) = \int_{-\infty}^{\ln w} \frac{1}{\sigma\sqrt{2\pi}} \cdot \exp\left[-\frac{(\ln x - \mu)^2}{2\sigma^2}\right] \mathrm{d}\ln x.$$

By applying Leibniz's rule, we can express the probability density function of x as:

$$g(w) = G'(w) = \frac{1}{w} \cdot \frac{1}{\sigma\sqrt{2\pi}} \cdot \exp\left[-\frac{(\ln w - \mu)^2}{2\sigma^2}\right].$$

If we define $s \equiv (\ln x - \mu)/\sigma$, $\mathbb{E}[(x)^r]$ is given by:

$$\begin{aligned}\mathbb{E}[(x)^r] &= \int_{-\infty}^{\infty} (x)^r \cdot \frac{1}{x\sigma\sqrt{2\pi}} \cdot \exp\left[-\frac{(\ln x - \mu)^2}{2\sigma^2}\right] \mathrm{d}x \\ &= \exp(r\mu) \cdot \exp\left[\frac{(r\sigma)^2}{2}\right] \cdot \int_{-\infty}^{\infty} \frac{1}{\sqrt{2\pi}} \cdot \exp\left[-\frac{(s - r\sigma)^2}{2}\right] \mathrm{d}s \\ &= \exp\left(r\mu + \frac{r^2\sigma^2}{2}\right).\end{aligned}$$

Therefore, when $\ln h_t^i \sim N\left(m_t, v_t^2\right)$ and $\ln z_t^i \sim N\left(-q^2/2, q^2\right)$, we obtain:

$$\mathbb{E}[(h_t^i)^\gamma] = \exp\left(\gamma m_t + \frac{\gamma^2 v_t^2}{2}\right), \qquad \mathbb{E}[z_t^i] = \exp\left(-\frac{q^2}{2} + \frac{q^2}{2}\right) = 1.$$

Appendix E: Proof of Proposition 6

Proof Given Eqs. 1 and 24, voter i's pre-election utility, $\mathbb{E}[U_t^i]$, is:

$$\begin{aligned}\mathbb{E}\left[U_t^i\right] &= \ln\left[(1-\xi)^{1-\rho}\xi^{\rho\beta}\right] + (1-\rho+\rho\beta)(1-\tau_t)\gamma\ln h_t^i \\ &\quad - (1-\rho+\rho\beta)(1-\tau_t)\cdot\frac{r^2}{2} - \rho\cdot\frac{q^2}{2} + \rho\ln\kappa + \tau_t(1-\rho+\rho\beta)\gamma m_t \\ &\quad + \tau_t(2-\tau_t)(1-\rho+\rho\beta)\cdot\frac{\gamma^2 v_t^2}{2} - \tau_t(\tau_t-1)(1-\rho+\rho\beta)\cdot\frac{r^2}{2} + W(\boldsymbol{Z}_t).\end{aligned} \tag{30}$$

Note, $V(I_t, h_t^i)$ is already determined when voters vote and, hence, we can treat it as a sunk benefit. Then, we can rewrite Eq. 30 as:

$$\begin{aligned}\mathbb{E}\left[U_t^i\right] &= J(\boldsymbol{P}_t) + H(\boldsymbol{P}_t)\cdot\ln h_t^i, \\ J(\boldsymbol{P}_t) &\equiv \ln\left[(1-\xi)^{1-\rho}\xi^{\rho\beta}\right] + \rho\ln\kappa - \rho\cdot\frac{q^2}{2} - (1-\rho+\rho\beta)(1-\tau_t)\cdot\frac{r^2}{2} \\ &\qquad + \tau_t(1-\rho+\rho\beta)\gamma m_t + \tau_t(2-\tau_t)(1-\rho+\rho\beta)\cdot\frac{\gamma^2 v_t^2}{2} \\ &\qquad - \tau_t(\tau_t-1)(1-\rho+\rho\beta)\cdot\frac{r^2}{2} + W(\boldsymbol{Z}_t) \\ H(\boldsymbol{P}_t) &\equiv (1-\rho+\rho\beta)(1-\tau_t)\gamma,\end{aligned}$$

Since $\ln h_t^i$ is a monotonic function, voters' preferences are the intermediate preference.[27] This means that the policy preferred by the median voter is the equilibrium policy. □

References

1. Aldrich, J.: Rational choice and turnout. Am. J. Polit. Sci. **37**, 246–278 (1993)
2. Alesina, A., Rodrik, D.: Distributive politics and economic growth. Q. J. Econ. **109**, 465–490 (1994)
3. Benabou, R.: Unequal societies: income distribution and the social contract. Am. Econ. Rev. **90**, 96–129 (2000)
4. Cavanagh, T.: Changes in american voter turnout, 1964–1976. Polit. Sci. Q. **96**, 53–65 (1981)
5. Chong, A., Olivera, M.: On compusory voting and income inequality in a cross-section of countries. Inter-American Development Bank Working Paper, 533 (2005)

[27] See Persson and Tabellini [27] for details of intermediate preference.

6. Crain, M., Deaton, T.: A note on political participation as consumption behaviort. Public Choice **32**, 131–135 (1977)
7. Downs, A.: An Economic Theory of Democracy. HarperCollins, New York (1957)
8. Feddersen, T., Pesendorfer, W.: The swing voter's curse. Am. Econ. Rev. **86**, 408–424 (1996)
9. Feddersen, T., Pesendorfer, W.: Abstention in elections with asymmetric information and diverse preferences. Am. Polit. Sci. Rev. **93**, 381–398 (1999)
10. Filer, J., Kenny, L., Morton, R.: Redistribution, income, and voting. Am. J. Polit. Sci. **37**, 63–87 (1993)
11. Fiorina, M.: The voting decision: instrumental and expressive aspects. J. Polit. **38**, 390–413 (1976)
12. Gentzkow, M.: Television and voter turnout. Q. J. Econ. **121**, 931–972 (2006)
13. Ghirardato, P., Katz, J.: Indecision theory: quality of information and voting behavior. California Institute of Technology Social Science Working Papers, 1106 (2002)
14. Hinich, M.: Voting as an act of contribution. Public Choice **36**, 135–140 (1981)
15. Jinwon, H., Tang, R.: Towards an optilmal resolution to information overload: an infomediary approach. In: Proceedings of the ACM 2001 International Conference on Supporting Group Work, Boulder, 2001
16. Kanazawa, S.: A possible solution to the paradox of voter turnout. J. Polit. **60**, 974–995 (1998)
17. Lassen, D.: The effect of information on voter turnout: evidence from a natural experiment. Am. J. Polit. Sci. **49**, 103–118 (2005)
18. Li, H., Zou, H.: Income inequality is not harmful for growth: theory and evidence. Rev. Dev. Econ. **2**, 318–334 (1998)
19. Lohmann, S.: A signaling model of informative and manipulative political action. Am. Polit. Sci. Rev. **87**, 319–333 (1993)
20. Lohmann, S.: Information aggregation through costly political action. Am. Econ. Rev. **84**, 518–530 (1994)
21. Lucas, R.: On the mechanics of economic development. J. Monet. Econ. **22**, 3–42 (1988)
22. Lupia, A.: Busy voters, agenda control, and the power of information. Am. Polit. Sci. Rev. **86**, 390–403 (1992)
23. Lupia, A., McCubbins, M.: The democratic dilemma. Cambridge University Press, Cambridge (1998)
24. Mueller, D., Stratmann, T.: The economic effects of democratic participation. J. Public Econ. **87**, 2129–2155 (2003)
25. Nardulli, J., Dalager, J., Greco, D.: Voter turnout in U.S. presidential elections: an historical view and some speculation. PS Polit. Sci. Polit. **29**, 480–490 (1996)
26. Persson, T., Tabellini, G.: Is inequality harmful for growth? Am. Econ. Rev. **84**, 600–621 (1994)
27. Persson, T., Tabellini, G.: Political Economics. MIT Press, Massachusetts (2000)
28. Popkin, S.: The Reasoning Voter: Communication and Persuasion in Presidential Campaigns. The University of Chicago Press, Chicago (1991)
29. Riker, W., Ordeshook, P.: A theory of the calculus of voting. Am. Polit. Sci. Rev. **62**, 25–42 (1968)
30. Reis, R.: Inattentive producers. Rev. Econ. Stud. **73**, 793–821 (2006a)
31. Reis, R.: Inattentive consumers. J. Monet. Econ. **53**, 1761–1800 (2006b)
32. Smith, J.: Race and human capital. Am. Econ. Rev. **74**, 685–698 (1984)
33. Strömberg, D.: Radio's impact on public spending. Q. J. Econ. **119**, 189–221 (2004)
34. Takii, K., Tanaka, R.: Does the diversity of human capital increase GDP?: a comparison of education systems. Osaka University OSIPP Discussion Paper, 06–05 (2006)