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INEQUALITY, TECHNOLOGY, AND THE SOCIAL CONTRACT

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ABSTRACT

The distribution of human capital and income lies at the center of a nexus of forces that shape a country's economic, institutional and technological structure. I develop here a unified model to analyze these interactions and their growth consequences. Five main issues are addressed. First, I identify the key factors that make both European-style "welfare state" and US-style "laissez-faire" social contracts sustainable.; I also compare the growth rates of these two politico-economic steady states, which are no Pareto-rankable. Second, I examine how technological evolutions affect the set of redistributive institutions that can be durably sustained, showing in particular how skill-biased technical change may cause the welfare state to unravel. Third, I model the endogenous determination of technology or organizational form that results from firms' tailoring the flexibility of their production processes to the distribution of workers' skills. The greater is human capital heterogeneity, the more flexible and wage-disequalizing is the equilibrium technology. Moreover, firms' choices tend to generate excessive flexibility, resulting in suboptimal growth or even self-sustaining technology-inequality traps. Fourth, I examine how institutions also shape the course of technology; thus, a world-wide shift in the technology frontier results in different evolutions of production processes and skill premia across countries with different social contracts. Finally, I ask what joint configurations of technology, inequality and redistributive policy are feasible in the long run, when all three are endogenous. I show in particular how the diffusion of technology leads to the "exporting" of inequality across borders; and how this, in turn, generates spillovers between social contracts that make it more difficult for nations to maintain distinct institutions and social structures.

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Introduction

The distribution of human capital and income lies at the center of a nexus of forces that shape a country's economic, institutional and technological structure. This paper develops a unified model to analyze these interactions and their implications for growth, emphasizing in particular the mechanisms that allow different socioeconomic structures to perpetuate themselves, and those pushing toward convergence.[1] The analysis centers around five main questions.

1. *Why do countries at similar levels of development choose widely different social contracts?* Redistribution –through taxes and transfers, unemployment and health insurance, education finance and labor market regulation– displays remarkable variations even among countries with similar economic and political fundamentals. I thus ask what makes both European-type welfare states and US-type, more laissez-faire social contracts sustainable in the long run, together with their respective levels of inequality.[2] I then examine the efficiency and growth properties of these two regimes (which cannot be Pareto ranked) and ask what shocks might cause each one to unravel. The model also sheds light on the contrasting historical development paths of North and South America, and on the more recent experience of East Asia versus Latin America.

2. *How does skill-biased technical and organizational change impact the viability of redistributive institutions?* Over the last twenty-five years, most industrialized countries experienced a considerable rise in wage inequality.[3] This trend is generally attributed to three main factors: skill-biased technical change, international trade (which lies outside the scope of this paper), and institutional change, such as the erosion of the minimum wage and the decline of unions. But minimum wages, labor market legislation and union power are endogenous outcomes, to the same extent as social insurance and education policy; and indeed, they evolved quite differently in Continental Europe or Canada and in the United States.[4] Analyzing redistributive institutions as a whole, I show how skill-biased technical change can cause the welfare state to unravel, and examine more generally how technological evolutions affect the set of social contracts that can be sustained in the long run.

The previous questions aim to explain differences in redistributive policies (together with their economic implications) and the role of technology in their evolution. The next two take the reverse perspective.

[1] The main channels through which inequality and redistributive institutions can in turn affect growth were exposited in Bénabou (1996).

[2] I shall limit my scope here to politico-economic persistence mechanisms that reflect differences in agents' economic interests and political power (Bénabou (2000), Saint Paul (2001), Hassler et al. (2003), Alesina, Glaeser and Sacerdote (2002)) rather than social norms (Lindbeck (1995)) or differences in beliefs about the mobility process and the determinants of individual income (Piketty (1995), Bénabou and Tirole (2002), Alesina and Angeletos (2003)).

[3] See, e.g. Autor, Katz and Krueger (1997) or Berman, Bound and Machin (1997).

[4] See, e.g., Freeman (1995), Fortin and Lemieux (1997), Lee (1999), or Acemoglu, Aghion and Violante (2001).

3. *What determines the types of technologies and organizational forms used by firms?* Production processes –and in particular their degree of skill bias– are themselves endogenous, adapting over time to the skills of the labor force.[5] I develop here a new and very tractable model of technology choice, based on the idea that firms tailor the *flexibility* of their production processes (substitutability between different labor inputs) to the distribution of human capital in the workforce. The main prediction is that the more heterogenous are workers' skill levels, the more flexible and wage-disequalizing the equilibrium technology will be. In a country like Japan, by contrast, production will involve much tighter complementarity between workers' tasks. Integrating this model with the previous analysis of human capital dynamics, I also show that firms' choices involve externalities that tend to result in excessive flexibility and a suboptimal growth rate, or even in self-sustaining technology-inequality traps.

4. *What types of societies and institutions are most conducive to the emergence of skill-biased technologies and organizational forms?* Through their influence on the distribution of human capital, public policies in the fiscal, labor market and especially educational arenas are important determinants of what innovations can be profitably developed and adopted; the same is true for immigration. One notes, for instance, that skill-biased technical change and reorganization occurred first, and to a greater extent, in the United States compared to Europe –and within the latter, more so in England than on the Continent. Combining the technology and policy components of the model, I show how a world-wide shift in the technological frontier leads to different evolutions of production processes and skill premia across countries with different social contracts.

Two extensive but essentially disconnected literatures have examined the economic determinants and consequences of redistributive policies on the one hand, those of biased technical change on the other.[6] Yet in reality both are endogenous, and jointly determined. The ability to conduct a unified analysis of human capital dynamics, technology and institutions is a novel and key feature of the framework developed in this paper. It makes it possible to address important questions such as the second, fourth and especially fifth ones on the list:

5. *What "societal models" –joint configurations of technology, inequality, and policy– are feasible in the long run? In particular, how does the diffusion of technology affect nations' ability to maintain their own redistributive institutions and social structures?* Analyzing the case of two countries linked by the (endogenous) diffusion of their domestically developed technologies, I show how inequality

[5] See, e.g., Kremer and Maskin (1996), Acemoglu (1998), Kiley (1999), Lloyd-Ellis (1999), and Vindigni (1992). Relatedly, Grossman and Maggi (2000) show how the skill distribution matters for international specialization, and Legros and Newman (1996) how the wealth distribution affects the organization of firms.

[6] See the previously cited references, as well as the other ones given throughout the paper.

tends to be "exported" to the less heterogeneous one. This mechanism, in turn, generates spillovers between the social contracts of different nations, transmitting even purely political shocks and potentially triggering "chain reactions" that can cause major shifts towards a common, and generally inegalitarian, outcome.

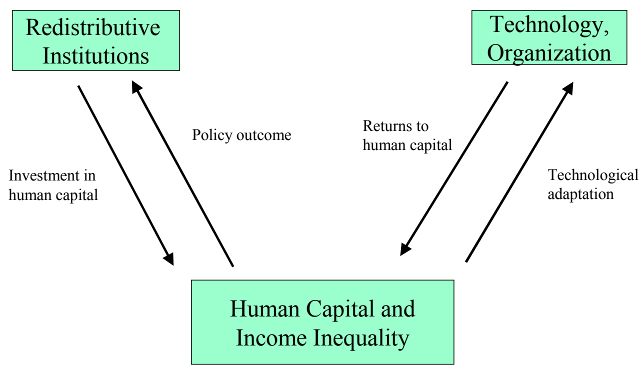

Figure 1: The links between inequality, technology and redistributive institutions

The paper is organized in two main parts, corresponding respectively to the left- and right-hand sides of Figure 1.[7] The first of these two feedback loops centers on political-economy interactions. I thus present in Sections I and II a model of inequality, growth and redistributive policy in a context of imperfect credit and insurance markets (based on Bénabou (2000)). I first analyze how macro and distributional dynamics are affected by redistributive policies, then how the latter are themselves determined from the preferences and political power of different social classes. Finally, I identify the conditions under which a single or multiple politico-economic steady states arise.

The second and most novel part of the paper incorporates the role of technology and its interactions with redistributive institutions. I first consider in Section III the impact of exogenous skill-biased technical change on inequality and the political equilibrium. I then study how technology responds to the composition of the labor force, through firms' choice of their degree of flexibility. In Section IV both sides of Figure I are brought together to analyze the long-run determination of institutions, technologies and the distribution of human capital. In Section V, finally, I show how technology diffusion leads to the "exporting" of inequality and international spillovers between social contracts. Section VI concludes. All proofs are gathered in the appendix.

[7] Each arrow on the diagram actually corresponds to a specific equation or proposition in the model. From left to right, these are (11), Proposition 3, (1) or later (28), and Proposition 8.

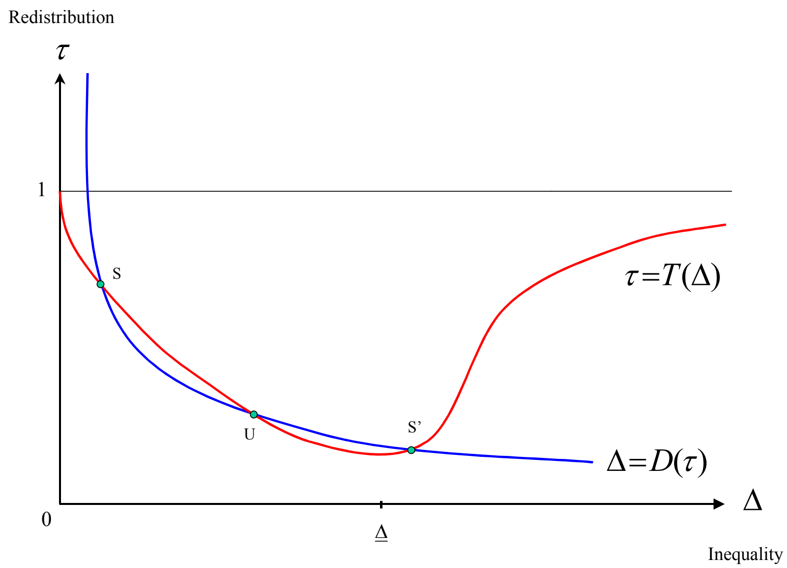

Figure 2: The two key relationships between inequality and redistribution.

I Inequality, Redistribution, and Growth

The model presented in this section (drawing on Bénabou (2000)) can be summarized by *two key relationships* between inequality and redistribution; both arise from imperfections in credit and insurance markets, and are illustrated on Figure 2.

The first locus summarizes the *political mechanism:* in each period, the equilibrium rate of redistribution chosen by voters is a U-shaped function $\tau = T(\Delta)$ of inequality in human capital, measured here as the variance of a lognormal distribution. The downward-sloping part of this curve, which is the crucial one, reflects a very general intuition: while asset market imperfections create a scope for efficient redistributive institutions (to provide social insurance and relax credit constraints), these institutions command much less support in an unequal society than in a relatively homogeneous one. Thus, starting from $\Delta = 0$, where there is unanimous support for the ex-ante efficient degree of redistribution, growing inequality increases the fraction of agents rich enough to lose from, and therefore oppose, all but relatively low levels of τ. The upward-sloping part of the curve, in contrast, is shaped by the standard skewness effect, which eventually dominates: rising numbers of poor will eventually impose more redistribution, well beyond the point where it ceases to be efficient.[8]

The second curve on Figure 2 represents the *accumulation mechanism:* since redistribution relaxes the credit constraints bearing on the poor's human capital investments, long-run inequality is a declining

[8] See, e.g., Alesina and Rodrik (1994) or Persson and Tabellini (1994) for models leading to such a positive slope. The empirical evidence (discussed at the end of this section) for both countries and US states provides little support for the standard view of a positive relationship between inequality and redistribution.

function $\Delta = T(\tau)$ of the rate of redistribution. When the two curves have several intersections, as illustrated on the figure, these correspond to *multiple politico-economic steady states* that are sustainable under the same fundamentals. One, with low inequality and high redistribution, corresponds to a European-type welfare state; the other, with the reverse configuration, to a US-type, more laissez-faire society.

In this and the next section I will derive the two loci from an explicit dynamic model, and identify the configurations of economic and political parameters under which alternative social models can coexist. In later sections I shall investigate how the two curves, and therefore the equilibrium set, are affected by exogenous technical change, then ultimately extend the analysis to the case where technology itself adapts endogenously to the distribution of skills in the population.

A *Production, Preferences and Policy*

The economy is populated by overlapping-generations families, $i \in [0,1]$. In generation t, adult i combines his human capital k_t^i with effort l_t^i to produce output, subject to a productivity shock z_t^i :

$$y_t^i = z_t^i \left(k_t^i\right)^{\gamma} \left(l_t^i\right)^{\delta}. \tag{1}$$

At this point the technology is exogenous and does not explicitly involve interactions among workers. Later on I will introduce a richer production structure, where agents with different skill levels perform complementary tasks and the degree of substitutability between them is optimally chosen by firms. The return to human capital γ and the mean of the productivity shocks z_t^i will then be endogenous functions of the current distribution of human capital. From the point of view of an individual worker-voter, however, this richer structure will retain an earnings function very similar to (1), so all the results obtained with this unconstrained reduced form will remain directly applicable.

Public policy or labor market institutions redistribute income through taxes and transfers, or a wage-equalization scheme, that transform each agent's gross earnings (or marginal revenue product) y_t^i into a disposable income $\hat{y}_t^i$, as specified further below. These resources finance both the adult's consumption, c_t^i, and his investment or educational bequest, e_t^i :

$$\hat{y}_t^i = c_t^i + e_t^i \tag{2}$$

$$k_{t+1}^i = \kappa\, \xi_{t+1}^i \,(k_t^i)^{\alpha}\,(e_t^i)^{\beta}, \tag{3}$$

where ξ_{t+1}^i represents the child's unpredictable ability, or simply luck, and $\alpha + \beta\gamma \leq 1$. There is thus no loan market for financing individual investments (e.g., children cannot be held responsible for the debts of their parents), and no insurance or securities market where the idiosyncratic risks z_t^i and ξ_{t+1}^i could be diversified away.[9] Both shocks are i.i.d. and lognormal with mean one, and initial endowments are also lognormally distributed across families: thus $\ln z_t^i \sim \mathcal{N}(-v^2/2, v^2)$, $\ln \xi_t^i \sim \mathcal{N}(-w^2/2, w^2)$ and $\ln k_0^i \sim \mathcal{N}(m_0, \Delta_0^2)$.

Agents' preferences over their own consumption, effort, and child's human capital are defined recursively over their lifetime. Once he has learned his productivity z_t^i, agent i chooses his effort and consumption to maximize:

$$\ln V_t^i \equiv \max_{l_t^i,\, c_t^i} \left\{(1-\rho)[\ln c_t^i - (l_t^i)^\eta] + \rho \ln E_t[k_{t+1}^i]\right\}. \tag{4}$$

The disutility of effort is measured by $\eta > 1$, which corresponds to an intertemporal elasticity of labor supply of $1/(\eta - 1)$. The discount factor ρ defines the relative weights of the adult's own felicity and of his bequest motive.[10]

At the beginning of period t, however, when evaluating and voting over redistributive policies, the agent does not yet know his lifetime productivity z_t^i. The resulting uncertainty over his *ex–post* utility level V_t^i is reflected in his *ex–ante* preferences, with a risk–aversion coefficient of a :

$$U_t^i \equiv \ln \left(E_t[(V_t^i)^{1-a} \mid k_t^i]^{1/(1-a)} \right), \tag{5}$$

This recursive specification allows a to parametrize the insurance value of redistributive policies, just as the labor supply elasticity $1/(\eta - 1)$ parametrizes the effort distortions.[11]

The redistributive policies over which agents vote are represented by simple, progressive schemes that map a market income y_t^i (marginal revenue product) into a disposable income $\hat{y}_t^i$, according to:

$$\hat{y}_t^i \equiv (y_t^i)^{1-\tau_t} (\tilde{y}_t)^{\tau_t}. \tag{6}$$

The break–even level $\tilde{y}_t$ is determined by the balanced-budget constraint, which requires that net transfers sum to zero. Thus, denoting per capita income by y_t, it must be that:

$$\int_0^1 (y_t^i)^{1-\tau_t} (\tilde{y}_t)^{\tau_t} \, di = y_t\,. \tag{7}$$

The elasticity τ_t measures the degree of *progressivity,* or equalization, of redistributive institutions.[12]

[9] The absence of any intertemporal trade is clearly an oversimplified (but quite common) representation of asset market incompleteness, making the model analytically tractable. Zhang (2001) extends a simplified version of the present model (with a zero-one policy variable and no political-economy mechanism) to allow for physical capital and financial bequests. He obtains similar results for the effects of inequality, plus new ones on convergence speeds to the steady-state.

[10] His (relative) risk–aversion with respect to the child's endowment k_{t+1}^i at that stage is normalized to zero, but this plays no role in any of the results. A dynastic specification of preferences (Bénabou (2002)) also leads to similar aggregate and distributional dynamics, but is less simple to work with.

[11] When $a \neq 1$ these recursive preferences are not time-separable (see, e.g., Kreps and Porteus (1979)), as risk-aversion differs from the inverse of the intertemporal elasticity of substitution in consumption, which by (4) remains fixed at one. This last assumption, common to many papers in the literature, helps make the model analytically solvable.

[12] When $\tau_t > 0$ the marginal rate rises with pretax income, and agents with average income are made better off: $\tilde{y}_t > y_t$. The elasticity of aftertax to pretax income is indeed the "right" measure of equalization: the posttax distribution induced by a fiscal scheme Lorenz–dominates the one induced by another (for all pretax distributions), if and only if the first scheme's elasticity is everywhere smaller (Fellman (1976)).

Three types of redistributive mechanisms can be considered here, being close to formally equivalent in this model. The first one, on which the exposition will generally focus, is that of fiscal policy, which equalizes disposable incomes through *taxes and transfers.* A second is *wage or earnings compression* through labor market institutions and policies favorable to workers with relatively low skills: minimum wage laws, union-friendly or right-to-strike regulations, firing costs, public sector pay and employment, etc.[13] The third one is *education finance,* where τ_t now applies only to human capital expenditures e_t^i, as opposed to all of income y_t^i. This may be achieved through a policy of school funding equalization across local communities, the presence of a centrally financed public-education system, or more generally by subsidizing differentially the education of rich and poor students.[14] Under either of the three above interpretations of τ_t, incentive compatibility requires that $\tau_t \leq 1$; on the other hand a regressive policy $\tau_t < 0$ cannot be ruled out a priori, and indeed one does observe such policies, typically in countries characterized by high inequality and a powerful ruling class.

B *Distributional Dynamics and Aggregate Growth*

Taking policy as parametrically given for the moment, I first consider the resulting economic decisions of individual agents, then the economy-wide dynamics of human capital and income.

Proposition 1 *Given a rate of redistribution* τ_t, *agents in generation* t *choose a common labor supply and savings rate:* $l_t = \chi\,(1-\tau_t)^{1/\eta}$ *and* $e_t^i = s\,\hat{y}_t^i$, *where* $\chi^\eta \equiv (\delta/\eta)(1-\rho+\rho\beta)/(1-\rho)$ *and* $s \equiv \rho\beta/(1-\rho+\rho\beta)$.

The fact that savings are unaffected is due to the imperfect-altruism assumption made regarding preferences.[15] Labor supply, on the other hand, declines in τ_t with an elasticity of $1/\eta$, and this single distortion will suffice to demonstrate how the efficiency costs and benefits of redistributive institutions shape the set of politico-economic equilibria.

Given Proposition 1, and substituting (6) into (3), the law of motion for human wealth is loglinear:

$$\begin{aligned} \ln k_{t+1}^i \;=\;& \ln \xi_{t+1}^i + \beta(1-\tau_t)\ln z_t^i + \ln\kappa + \beta\ln s \\ & +(\alpha+\beta\gamma(1-\tau_t))\ln k_t^i + \beta\delta(1-\tau_t)\ln l_t + \beta\tau_t \ln \tilde{y}_t. \end{aligned} \tag{8}$$

[13] With the "autarkic" production function (1) the equivalence between the wage-income-equalization and the fiscal-redistribution interpretations of τ_t is immediate. It continues to hold when we move in Section III.B to a richer production structure with interacting agents.

[14] See Bénabou (2000) for this version of the model. Some of the formulas change slightly from those presented here for fiscal policy, but without affecting the qualitative nature of any of the results. There are, on the other hand, important quantitative differences between the growth and welfare implications of the two policies; see Bénabou (2002) and Sheshadri and Yuki (2000) for comparative analyzes. Previous models of redistribution centering on education finance include Becker (1964), Loury (1981), Glomm and Ravilkumar (1992), Saint-Paul and Verdier (1993), Bénabou (1996b) and Fernandez and Rogerson (1996). On the empirical side, see Krueger (2002) for a comprehensive summary and discussion of the evidence on targeted education and training policy interventions, from preschool to the college level.

[15] In Bénabou (2002) I develop and calibrate a version of the present model with dynastic preferences, where τ_t does affect the savings rate. On the other hand, agents are then able (and will indeed want) to use additional policy instruments, such as consumption taxes and investment subsidies, to alleviate this distortion.

This linearity reflects the absence of any non-convexities in the model, making clear that the multiplicity of equilibria will arise solely through the general-equilibrium feedback from the income distribution onto the political determination of τ_t.[16] These simple conditional dynamics also imply that human capital and income always remain lognormally distributed across agents:

$$\ln k_t^i \sim \mathcal{N}(m_t, \Delta_t^2), \tag{9}$$

$$\ln y_t^i \sim \mathcal{N}(\gamma m_t + \delta \ln l_t - v^2/2, \gamma^2 \Delta_t^2 + v^2), \tag{10}$$

where m_t and Δ_t^2 evolve according to two simple linear difference equations obtained by taking means and variances in (8), and given in the appendix. Since the growth of mean income y_t is of more direct economic interest than that of mean log-income m_t, I present here the equivalent characterization of the economy's dynamic path in terms of two linear difference equations in Δ_t^2 and $\ln y_t = m_t + \Delta_t^2/2$.

Proposition 2 *The distributions of human capital and income at time t are given by (9)-(10), where $l_t = \chi(1-\tau_t)^{1/\eta}$. The evolution of inequality across generations is governed by*

$$\Delta_{t+1}^2 = (\alpha + \beta\gamma(1-\tau_t))^2 \, \Delta_t^2 + \beta^2(1-\tau_t)^2 \, v^2 + w^2, \tag{11}$$

and the growth rate of aggregate income by:

$$\ln(y_{t+1}/y_t) = \ln\tilde{\kappa} - (1-\alpha-\beta\gamma)\ln y_t + \delta(\ln l_{t+1} - \alpha \ln l_t) - \mathfrak{L}_v(\tau_t)v^2/2 - \mathfrak{L}_\Delta(\tau_t)\gamma^2\Delta_t^2/2, \tag{12}$$

where $\ln\tilde{\kappa} \equiv \gamma(\ln\kappa + \beta\ln s) - \gamma(1-\gamma)w^2/2$ is a constant and

$$\mathfrak{L}_v(\tau) \equiv \beta\gamma(1-\beta\gamma)(1-\tau)^2 \geq 0,$$

$$\mathfrak{L}_\Delta(\tau) \equiv \alpha + \beta\gamma(1-\tau)^2 - (\alpha + \beta\gamma(1-\tau))^2 \geq 0.$$

Equation (11) shows how inequality in the next generation stems from three sources: the varying abilities of children (w^2), shocks to family income (v^2), and differences in parental human capital (Δ_t^2), which matter both through family income and at-home transmission. Redistribution equalizes the disposable resources available to finance educational investments (but not social backgrounds), thus limiting both cross-sectional inequality and the *persistence* of family wealth, $\alpha + \beta\gamma(1-\tau_t)$; conversely, it increases *social mobility.*

Equation (12) makes apparent the growth losses from inequality due to credit constraints, and how redistribution's impact on growth involves a tradeoff between incentive and investment-allocation effects.[17]

[16] Or / and a feedback from the distribution onto the technology γ, once it is endogenized later on. By contrast, nearly all models in the literature that feature multiple equilibria rely on investment thresholds (e.g., Galor and Zeira (1993), Banerjee and Newman (1993)), indivisibilities in effort (Piketty (1997)), or non-homotheticity in preferences (e.g., Moav (2002)). For a discussion of indivisibilities, see also Mookerjee and Ray (2003).

[17] See Bénabou (1996b) for an overview of the literature on the relationship between inequality and growth, which is not the main focus of the present paper. In particular, inequality can also have positive effects on growth when there are non-

The effort distortion corresponds to the term in δ, which declines with parallel increases in τ_t and τ_{t+1}. The reallocation of human capital investments across differentially wealth-constrained agents is captured by the terms in $\mathfrak{L}_v(\tau_t)$ and $\mathfrak{L}_\Delta(\tau_t)$. When $\alpha = 0$ both are equal, and proportional to the concavity $\beta\gamma(1-\beta\gamma)$ of the common accumulation technology facing all families: differences in parental human capital and productivity shocks simply combine into variations in disposable income, $(1-\tau_t)^2\left(\gamma^2\Delta_t^2 + v^2\right)$, which credit constraints then translate into inefficient variations in investment, reducing overall growth proportionately. When $\alpha > 0$, however, disparate family backgrounds k_t^i represent complementary inputs that generate differential returns to investment, thus reducing the desirability of equalizing resources. Thus $\mathfrak{L}_\Delta(\tau)$ now differs from $\mathfrak{L}_v(\tau)$, and is minimized for $\tau = (1-\alpha-\beta\gamma)/(1-\beta\gamma)$, which decreases with α.

The term in $-\ln y_t$ in the growth equation, finally, reflects the standard convergence effect. It disappears under constant aggregate returns, namely when $\alpha + \beta\gamma = 1$, or when the constant κ in (3) is replaced by a knowledge spillover such as

$$\kappa_t \equiv \left(\int_0^i (k_t^i)^\gamma\right)^{(1-\alpha-\beta\gamma)/\gamma}. \tag{13}$$

This last variant yields an *endogenous-growth* version of the model, where all the predictions obtained with a constant κ in (12) now directly transpose from short-run growth and long-run per capita income to *long-term growth rates.*

Are the potential growth-enhancing effects of redistributive policies in the presence of credit constraints significant, or trivial compared to the standard deadweight losses? While the answer must ultimately come from empirical studies of specific policy programs or experiments, recent quantitative models suggest very important long-run effects, ranging from several percentage points of steady-state GDP to several percentage points of long-run growth, depending on the presence of accumulated factors, such as physical capital or knowledge spillovers, that complement individual human capital. Calibrating to US data a model with neither effort distortions nor complementarities, Fernandez and Rogerson (1998) find that complete school finance equalization raises long-run GDP by 3.2 %. In a model with both educational and financial bequests, Sheshadri and Yuki (2000) find that a mix of fiscal and educational redistribution that approximates current US policies raises long-run income by 13.5%, relative to laissez-faire. This more substantial impact primarily reflects the induced adjustment of physical capital, but it remains a level effect due to decreasing returns to the two types of capital together. In a dynastic-utility version of the present model with endogenous growth (Bénabou (2002)) I find that the growth-maximizing value for fiscal redistribution is $\tau_{fisc} = 21\%$, which corresponds to a share of redistributive transfers in GDP of 6%; in spite of reduced labor supply this raises the long-run growth rate by 0.5 percentage points. Under

convexities in either the investment technology (e.g., Galor and Zeira (1993)) or in preferences (e.g., Galor and Moav (1999)). For recent contributions to the empirical debate, see Forbes (2000) and Banerjee and Duflo (2003).

the alternative policy of progressive education finance, the growth-maximizing equalization rate for school expenditures is $\tau_{educ} = 62\%$, which raises long-run growth by 2.4 percentage points. In both cases, the efficient policy involves the top 30% of families subsidizing the bottom 70%, whether through the fiscal or the education system.

C Voter Preferences, Political Power, and Equilibrium Policy

I now turn to the determination of policy, which reflects both individual citizens' preferences and the allocation of power in the political system. In each generation, before the productivity shocks z_t^i are realized, agents vote on the rate of redistribution τ_t to which they will be subject; again, this could be through the fiscal system, labor market regulation, or education finance. Applying Propositions 1 and 2 to equations (4)-(5), an individual i's intertemporal welfare U_t^i can be computed from (5) as a function of the proposed policy τ_t, his endowment k_t^i, and the overall distribution of human capital (m_t, Δ_t), which is the system's state variable.[18] Defining the composite efficiency parameter

$$B \equiv a + \rho(1-a)(1-\beta) \geq 0, \tag{14}$$

whose interpretation is is given below, the resulting first-order condition for agent i's ideal tax rate takes the form:

$$\frac{\partial U_t^i}{\partial \tau_t} = (1-\rho+\rho\beta)\left[\gamma(m_t - \ln k_t^i) - \frac{\delta}{\eta}\left(\frac{\tau}{1-\tau}\right) + (1-\tau)(\gamma^2\Delta_t^2 + Bv^2)\right] = 0. \tag{15}$$

The first term inside the brackets, which disappears when summing across agents, reflects the basic redistributive conflict: since τ_t reallocates resources (spent on both consumption and children's education) from rich to poor households, the latter want it to be high, and the former, low. The next two terms represent the *aggregate welfare cost* and *aggregate welfare benefit* of a marginal increase in τ_t. First, there is the deadweight loss due to the distortion in effort: it is proportional to the labor supply elasticity $1/\eta$, and vanishes at $\tau = 0$. Second, the term $(1-\tau_t)(\gamma^2\Delta_t^2 + Bv^2)$, which is maximized for $\tau_t = 1$, embodies the (marginal) efficiency gains that arise from better insurance and the redistribution of resources towards more severely credit-constrained investments. Indeed it is clear from (14) that the composite parameter B multiplying the variance of adults' income shocks v^2 is monotonically related to both *risk–aversion* a and to the extent of *decreasing returns* in human-capital investment, $1-\beta$.[19] As to initial income inequality,

[18] See the appendix. Note that due to the model's overlapping–generations structure, voting involves no intertemporal strategic considerations.

[19] More specifically, under constant returns ($\beta = 1$) the term $(1-\rho+\rho\beta)Bv^2$ reduces to $a(1-\tau)v^2$, which is the insurance value of a marginal reduction in the lifetime resource risk $(1-\tau)^2v^2/2$ faced by agents. Conversely, for risk–neutral agents who care only about their offspring ($a = 0,\ \rho = 1$) that same term becomes $\beta(1-\beta)(1-\tau)v^2$, which is the gain in expected (and aggregate) human capital growth resulting from a marginal decrease in the variability of post-tax resources $(1-\tau)^2v^2/2$, given the concavity of the investment technology.

the term $\gamma^2\Delta_t^2$ reflects two motives for redistribution.[20] First, relaxing preexisting credit constraints tends to increase overall growth (see the last term in (12)), and therefore also average welfare. Second, with concave (logarithmic) utility functions, average welfare increases whenever individual consumptions (of c_t^i and k_{t+1}^i) are distributed more equally. Equivalently here, this captures the effect of skewness: given m_t, a higher Δ_t^2 implies a higher per capita income $\ln y_t = m_t + \Delta_t^2/2$, making redistribution more attractive for the median voter, and more generally at any given level of k_t^i.

From this analysis it easily follows that agent i's preferred tax rate, obtained as the unique solution $\tau_t^i < 1$ to the quadratic equation (15), decreases with his endowment k_t^i and increases with the ex-ante benefits from redistribution Bv^2. Similarly, $\left|\tau_t^i\right|$ decreases with $1/\eta$, as a more elastic labor supply magnifies the distortions that result from redistributive policies –whether progressive, $\tau > 0$, or regressive, $\tau < 0$.

I now turn from the preferences of different classes of voters to their political power or influence over the process that determines the actual τ_t. Even in advanced democracies, poor and less educated individuals have a lower propensity to register, turn out to vote and give political contributions, than better-off ones. For voting itself the tendency is relatively moderate, whereas for contributing to campaigns it is drastic. Even for political activities that are time- rather than money-intensive, such as writing to Congress, attending meetings, trying to convince others, etc., the propensity to participate rises sharply with income and education. These facts are documented for instance in Rosenstone and Hansen (1993), while Bartels (2002) provides a striking study of how they translate into disproportionate political influence. Studying the roll calls of US senators in three Congresses he finds that their votes are more responsive, by a factor ranging from 3 to 15, to the views of their constituents located the 75^{th} income percentile than to those of the 25^{th}; and again more responsive, by a factor of 2 to 3, to the views of the 99^{th} percentile than to those of the 75^{th}. In less developed countries there is also extensive vote-buying, clientelism, intimidation and the like, which are likely to result in even more bias.

To summarize this political influence of human and financial wealth in a simple manner I shall assume that *the pivotal voter is located at the* $100 \times p^*$ *-th percentile* of the distribution, where the critical level p^* can be any number in $[0, 1]$. A perfect democracy corresponds to $p^* = 1/2$, while an imperfect one where participation or influence rises with social status corresponds to $p^* > 1/2$.[21] Given that k_t^i is here log-normally distributed, an equivalent but more convenient measure of the political system's departure from the democratic ideal is

[20] See Bénabou (2000) for the exact decomposition.

[21] Since individual preferences are single-peaked and the preferred policy is monotonic in k_t^i, it is easy to show that such a critical p^* is a sufficient statistic for any *ordinal* weighing scheme where each agent's opinion is affected by a weight, or relative probability of voting, ω^i (with $\int_0^1 \omega^j \, dj = 1$), that increases with his *rank* in the distribution of human capital or income. Alternatively, political influence may depend on individuals' income *levels.* Thus, with ω^i proportional to $(y^i)^\lambda$ it can be shown that the pivotal voter has rank $p^* = \Phi(\lambda\Delta)$, so that λ in (16) is simply replaced by $\lambda\Delta$. As intuition suggests, this alternative formulation only reinforces the key result that efficient redistributions may decline with inequality, since it implies that the political system tends to becomes more biased towards the wealthy as inequality rises.

$$\lambda \equiv \Phi^{-1}(p^*), \tag{16}$$

where $\Phi(\cdot)$ denotes the c.d.f. of a standard normal. I shall refer to λ as the degree of *wealth bias* in the political system, and focus on the empirically relevant case where $\lambda > 0$.[22] Given the location of the pivotal voter, the policy outcome is simply obtained by setting $\ln k_t^i - m_t = \lambda\Delta_t$ in the first-order condition $\partial U_t^i/\partial\tau = 0$. This yields the quadratic equation:

$$\frac{1}{1-\tau_t} = \frac{1}{\lambda}\left[\frac{\gamma^2\Delta_t^2 + Bv^2}{\gamma\Delta_t} - \frac{\tau_t}{\eta\gamma\Delta_t(1-\tau_t)^2}\right]. \tag{17}$$

When labor supply is inelastic ($1/\eta = 0$), it is immediately apparent that this equilibrium tax rate is U–shaped in Δ_t, and minimized where $\gamma^2\Delta^2 = Bv^2$. This is true more generally.

Proposition 3 *The rate of redistribution $\tau_t = T(\Delta_t)$ chosen in generation t is such that:*

1) τ_t increases with the ex–ante efficiency gain from redistribution Bv^2, and decreases with the political influence of wealth, λ.

2) $|\tau_t|$ decreases with the elasticity of labor supply $1/\eta$.

3) τ_t is U-shaped with respect to inequality Δ_t. It starts at the ex–ante optimal rate $T(0) > 0$, declines to a minimum at some $\underline{\Delta} > 0$, then rises back towards $T(\infty) = 1$. The larger Bv^2, the wider the range $[0, \underline{\Delta})$ where $\partial\tau_t/\partial\Delta_t < 0$.

The first two results show that equilibrium policy depends on the costs and benefits of redistribution and on the allocation of political influence in a sensible manner. The third one confirms the key insight that efficient redistributions may *decrease* with inequality; more specifically, it yields the U-shaped function $\tau = T(\Delta)$ shown on Figure 2. The underlying intuition is simple, and very general: a) when distributional conflict $\gamma\Delta$ is small enough relative to the ex-ante efficiency gains Bv^2, there is widespread support for the redistributive policy, so its equilibrium level is high; b) as inequality rises, so does the proportion of agents rich enough to be net losers from the policy, who will *block* all but relatively low levels of τ_t; c) at still higher levels of inequality, the standard skewness effect eventually dominates: there are so many poor that they *impose* high redistribution, even when it is very inefficient.[23]

It is now well-recognized that the standard median-voter model's prediction of a positive effect of inequality on redistribution fails to explain the empirical patterns actually observed, both across countries (see, e.g., Perotti (1996), Bénabou (1996a, 2000), Alesina et al. (2002)) and within them (see Rodriguez

[22] Recent papers that aim to endogenously explain the allocation of political power in a country (corresponding here to the parameter λ) include Bourguignon and Verdier (2000), Pineda and Rodriguez (2000), Acemoglu and Robinson (2000), and Baland and Robinson (2003).

[23] A similar form of non-monotonicity (U-shape, or even declining throughout for λ high enough) is obtained with a Pareto distribution by Lee and Romer (1998).

(1999) for panel-data tests on US states). Among developed countries, in particular, the relationship is in fact negative (Pineda and Rodriguez (2000). The present framework explains how and when greater inequality will indeed *reduce* redistribution, or even result in *regressive* policies –both in the short run (Proposition 3) and in the long-run, when both are endogenous (Proposition 4 below). Furthermore, the distinctive *non–monotonic* relationship predicted by the model turns out to have empirical support: in tests using cross-country data, Figini (1999) finds in a significant U-shaped effect of income inequality on the shares of tax revenues and government expenditures in GDP; De Mello and Tiongson (2003) find a similar pattern for government transfers.

II Sustainable Social Contracts

A *Dynamics and Steady States*

The joint evolution of inequality and policy is described by the recursive dynamical system:

$$\begin{cases} \tau_t & = & T(\Delta_t) \\ \Delta_{t+1} & = & \mathfrak{D}(\,\Delta_t, \tau_t) \end{cases} \tag{18}$$

where $T(\Delta_t)$ is given by Proposition 3 and $\mathfrak{D}(\,\Delta_t, \tau_t)$ by (11). Under a time–invariant policy, in particular, long–run inequality decreases with redistribution:

$$\Delta_\infty^2 = \frac{w^2 + \beta^2(1-\tau)^2 v^2}{1-(\alpha+\beta\gamma(1-\tau))^2} \equiv D^2(\tau). \tag{19}$$

A steady-state equilibrium is an intersection of this downward-sloping locus, $\Delta = D(\tau)$, with the U-shaped curve $\tau = T(\Delta)$, as illustrated in Figure 2. The following key proposition identifies the conditions under which multiple intersections occur.

Proposition 4 *Let $1-\alpha < 2\beta\gamma$. When the normalized efficiency gain B is below some critical value $\underline{B}$ there is a unique, stable, steady–state. When $B > \underline{B}$, on the other hand, there exist $\underline{\lambda}$ and $\bar{\lambda}$ with $0 < \underline{\lambda} < \bar{\lambda}$, such that:*

1) For each λ in $[\underline{\lambda}, \bar{\lambda}]$ there are (at least) two stable steady states.[24]

2) For $\lambda < \underline{\lambda}$ or $\lambda > \bar{\lambda}$ the steady–state is unique.

These results can shed light on a number of important issues and puzzles raised in the introduction.

First, they explain how countries with similar economic and political fundamentals can nonetheless sustain very different redistributive institutions, such as a *European-style welfare state* and a *US-style*

[24] See Bénabou (2000) for additional results on the number of stable steady-states ($n \leq 4$), including conditions ensuring that $n = 2$.

laissez-faire social contract. Notably, these two societies cannot be Pareto ranked. Recall also that τ_t can be equally interpreted as describing tax-and-transfer policy, labor market regulation, or (with some minor changes) education finance policy. Moreover, it is clear that the model's key mechanism makes these multiple dimensions of policy complementary, so that they will tend to covary positively across countries, as indeed they do empirically. A more egalitarian education system, for instance, tends to reduce income inequality, which in turn increases political support for fiscal redistribution or labor-earnings compression –and vice-versa. Summarizing a large collective research project on Sweden, Freeman (1995) emphasizes the presence of such complementarities, describing *"a highly interrelated welfare state and economy in which many parts fit together (be they subsidies, taxes, wage compression etc.)".*

Second, the two conditions required for multiplicity embody *very general intuitions* that are easily understood in the context of Figure 2. To start with, the ex-ante welfare benefits of redistribution must be high enough, relative to the costs.[25] Otherwise the T curve will be upward-sloping except over a very narrow initial range, and consequently have a unique intersection with the D curve; economically speaking, we would be close to the standard, complete-markets case. In addition, the political power of the wealthy must lie in some intermediate range, otherwise the T curve will lie too high or too low relative to the D curve, and again there will be a unique intersection, with high inequality and low redistribution, or vice-versa.

Third, while in the short-run the relationship is non-monotonic, there emerges in the long–run a *negative* correlation between inequality and redistribution, as indeed one observes between the United States and Europe, or among advanced countries in general (Pineda and Rodriguez (2000)).

Fourth, *history matters* in an important and plausible way: temporary shocks to the distribution of wealth (immigration, educational discrimination, demand shifts) as well as to the political system (slavery, voting rights restrictions) can permanently move society from one equilibrium to the other, or more generally have long-lasting effects on inequality, growth, and institutions. In particular, the model provides a formalization of Engerman and Sokoloff's (1998) thesis about the historical origins of South and North America's very different development paths, which they trace back to the former set of New World colonies having had much higher initial inequality Δ_0, and a much more concentrated power structure λ_0, than the latter.[26]

Finally, the model also shows that *different sources of inequality* have different effects on redistributive institutions –which, in particular, sheds doubt on the possibility of empirically estimating a catch-all relationship between inequality and redistribution, or inequality and growth. Indeed, one can show (provided

[25] The claim with respect to the benefits is clear from Proposition 4; with respect to the costs one can show, under additional technical assumptions, that the threshold $\underline{B}$ shifts up as the labor supply elasticity $1/\eta$ rises.

[26] This, in turn, was due to reasons linked to the technologies required for the different goods these colonies were producing –a point I shall come back to in Section III.A.

$1/\eta$ is not too large) that the threshold for multiplicity $\underline{B}$ is a decreasing function of the variance ratio v^2/w^2, with $\lim_{v/w \to 0}(\underline{B}) = +\infty$ and $\lim_{v/w \to +\infty}(\underline{B}) = 0$. Quite intuitively, income *uncertainty* interacts with the incompleteness in insurance and credit markets in generating ex ante efficiency gains from redistribution, as reflected by the term Bv^2 in (17). By contrast, a greater variance w^2 of the endowments that agents receive *prior* to choosing policy increases the distributional conflict between *identifiable losers and gainers* from the policy. Thus, whereas an increase in the variability of sectoral shocks (similar to v^2) will lead to an expansion of the welfare state, a surge in immigration that results in a greater heterogeneity of the population (similar to a rise in w^2) can easily lead to cutbacks, or even a large–scale dismantling. We shall observe similar effects when studying the political implications of skill-biased technical change.

B *Which Societies Grow Faster?*

As mentioned earlier, the steady states corresponding to different social contracts are not Pareto–rankable: rich enough agents always prefer a more laissez-faire society, while those who are poor enough always want more of a welfare state. One may still ask, however, how these two social models compare in terms of aggregate growth. This question is important first for its policy content, and second to know whether one should expect any empirical relationship between inequality and growth, when account is taken of the fact that *both* are endogenous. The answer hinges on the basic tradeoff, discussed earlier, between the distortions induced by redistribution and its beneficial effect on credit–constraints (magnified, in the long run, by the fact that it also reduces income inequality $\gamma\Delta_\infty$). This is made clear by the following results, which apply equally in the short and in the long run.[27]

Proposition 5 *Compared to a more laissez-faire alternative τ', a more redistributive social contract $\tau > \tau'$ is associated with lower inequality, and*

1) has higher growth when tax distortions are small $(1/\eta \approx 0)$ *relative to those induced by credit constraints on the accumulation of human capital* $(\beta\gamma < 1)$;

2) has lower growth when tax distortions are high $(1/\eta > 0)$ *and the credit–constraint effect is weak* $(\beta\gamma \approx 1)$.

The first scenario, of *"growth-enhancing redistributions",* seems most relevant for developing countries, where capital markets are less well-functioning, and for redistribution through public investments in human capital and health. One may contrast here the paths followed by East Asia and Latin America in those respects. The result may also help understand why regression estimates of the effects of social and educational transfers on growth are often significantly positive, or at least rarely significantly negative.

[27] See Section I.B for the simple correspondence between the stationary and the endogenous-growth versions of the model, where policy affects growth in the short and the long-run respectively.

The second, *Eurosclerosis"* scenario can account for why Europeans consistently choose more social insurance than Americans –at the cost of higher unemployment and slower growth –even though they are not necessarily more risk-averse. The intuition is that, in more homogenous societies, there is less erosion of the consensus over social insurance mechanisms which, ex–ante, would be valued enough to compensate for lesser growth prospects.[28]

Putting the two cases together, finally, Proposition 5 can also be related to the empirical findings of Barro (2000) that inequality tends to be negatively associated with subsequent growth in poor countries, but positively associated with it in richer ones. To the extent that poor countries are also those where credit markets are least developed, Proposition 5 predicts that inequality-reducing policies will give rise to just such a dichotomy.

III Technology and the Social Contract

I shall now extend the model to analyze how technology and redistributive institutions both affect inequality and respond to it, and consequently how they *influence each other* –as described on Figure 1. Of particular interest are the following questions. First, how does technical change impact the sustainability of welfare-state and laissez-faire social contracts? Second, what types of societies are likely to be leaders or early adopters in developing or implementing flexible, skill-biased technologies or organizational forms? More generally, how do the skill distribution among workers and the production side of the economy shape each other, through human capital investments and technology choices? Finally, what happens in the long run when technological and institutional factors evolve interdependently –within a country, and possibly even across countries?

A *Exogenous Technical Change and the Viability of the Welfare State*

I first examine here how technical or organizational change that increases the return to human capital affects redistributive institutions. This policy response represents an additional channel through which technological evolutions affect the income distribution, in addition to their direct impact via the wage structure.

Figure 3 illustrates the effects of an increase in γ, the coefficient on human capital in the production and earnings function (1). As will from now on be made explicit in the notation, this affects both of the key curves describing the inequality-redistribution nexus:

[28] For the specific case of unemployment insurance, Hassler et al. (1999) provide a complementary explanation, based on interactions with workers' specialization (or lack thereof) that can result in multiple equilibria.

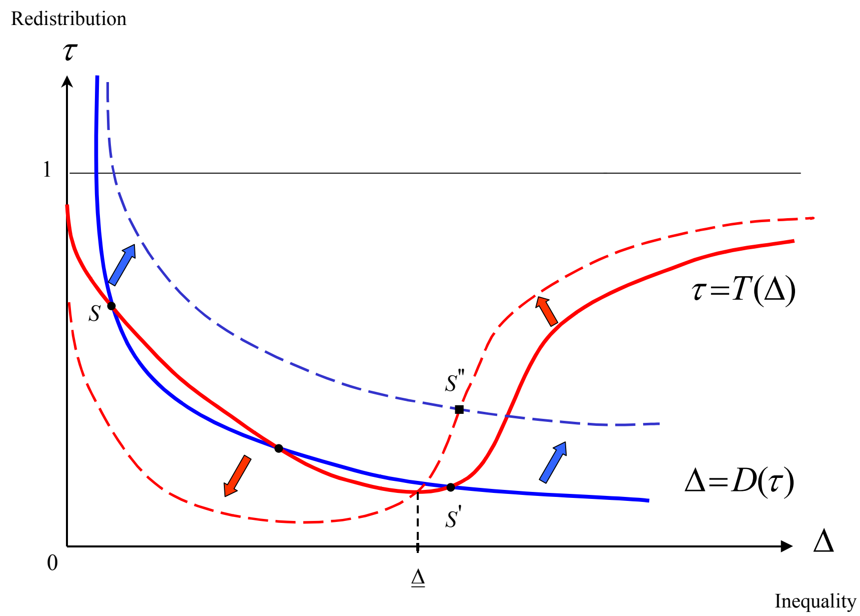

Figure 3: The effects of an increase in the returns to human capital, $\gamma = (\sigma - 1)/\sigma$.

i) The intergenerational-transmission locus $\Delta = D(\tau;\gamma)$ shifts up, and becomes less steep: for given human capital inequality Δ_t and policy τ there is more inequality in incomes $\gamma\Delta_t$, hence also in investments, and consequently more inequality of human capital (and of course income) in all subsequent periods.[29]

ii) The policy locus $\tau = T(\gamma\Delta)$ shifts down over $[0, \underline{\Delta})$, and up over $(\underline{\Delta}, +\infty)$: since what matters for the political outcome is *income* inequality $\gamma\Delta$ (see (17), an increase in γ for given Δ has the same U-shaped effect on redistribution as an increase in Δ for given γ –initially lowering τ, then raising it.

Figure 3 directly yields a local analysis of the more egalitarian, welfare-state equilibrium –and more generally, of any steady state that occurs along the declining portion of the T locus.[30]

Proposition 6 *Let (Δ, τ, γ) be such that (Δ, τ) is a stable steady state under the technology γ, with $\Delta < \underline{\Delta}(Bv^2;\gamma)$. A marginal increase in γ results in higher long run human capital and income inequality, as well as in less redistribution.*

[29] Recall that a worker's human capital reflects his individual ability, family background, and parental investment in education: $k_t^i = \kappa\, \xi_t^i\, (k_{t-1}^i)^\alpha\, (e_{t-1}^i)^\beta$. The kind of technical change considered here raises the return to all three components of k_t^i equally. In Galor and Tsiddon (1997) by contrast, major innovations raise the relative return to pure ability, while subsequent learning-by-doing innovations raise the relative return to inherited human capital. In Galor and Moav (2000) human capital is also sector-specific, and therefore eroded by new technologies, to an extent that decreases with individual ability. In these models technological innovations can thus raise as well as lower integenerational mobility.

[30] For steady-states that occur on the rising part, local comparative statics are ambiguous. Note, however, that in versions of the model where power inequality rises with income or human wealth inequality –meaning that λ increases with Δ (see footnote 21)– the declining portion of the locus is wider and the increasing portion reduced, making it easier to rule out such equilibria. For instance, if political power ω_i is proportional to $(y_i)^\lambda$ –e.g., "one dollar, one vote" for $\lambda = 1$– then λ is simply replaced by $\lambda\Delta$ everywhere. As seen from (17), for $1/\eta = 0$ the $T(\gamma\Delta)$ curve is then decreasing throughout.

The policy response thus amplifies the direct effect of skill-biased technical progress on disposable incomes –and, over time, on the distributions of human capital and earnings. Figure 3 also suggests that it can have, in the long run, much more drastic consequences for redistributive institutions: starting from a situation with multiple steady states, an increase in γ tends to undermine the sustainability of the "Welfare State" equilibrium. Similarly, we shall see that starting from a configuration with a single "Welfare-State" it can make a second, "Laissez-Faire" equilibrium appear. Such a *global* analysis is potentially quite complicated, however, since in general there may be more than two stable equilibria, and some may also occur in the upward-sloping portion of the $\tau = T(\gamma\Delta)$ locus, where the policy response has a dampening rather than an amplifying effect on inequality. To demonstrate the most interesting insights, I shall therefore impose some simplifying assumptions. First, I restrict voters to a choice between only two policies:

- A generous *"Welfare State"* social contract, corresponding to a relatively high rate of redistribution $\bar{\tau} \in (0, 1)$;
- A more *"Laissez Faire"* social contract, corresponding to a relatively low rate of redistribution $\underline{\tau} \in (0, \bar{\tau})$.

Once again, τ can be interpreted as corresponding to either fiscal redistribution, wage compression through labor market regulation, or education finance progressivity. To further simplify the problem I abstract from labor supply distortions ($1/\eta = 0$) and assume that B is large enough that both potential steady states are always on the downward-sloping part of the $\tau = T(\Delta\gamma)$ curve, which is the one of most interest.[31]

Given an initial distribution of human capital Δ_t, the more redistributive policy $\tau_t = \bar{\tau}$ is adopted over $\tau_t = \underline{\tau}$ if $U_t^i(\bar{\tau}) > U_t^i(\underline{\tau})$ for at least a critical fraction $p^* \equiv \Phi(\lambda)$ of the population. Note from (15) that with $1/\eta = 0$, $\partial U_t^i / \partial \tau_t$ is linear in τ_t, so the preceding inequality evaluated at $\ln k_t^i = m_t + \lambda \Delta_t$ takes the form:

$$(\bar{\tau} - \underline{\tau}) \left[\gamma \lambda \Delta_t + (1 - \underline{\tau}) \left(\gamma^2 \Delta_t^2 + B v^2 \right) \right] < (\bar{\tau} - \underline{\tau})^2 \left(\gamma^2 \Delta_t^2 + B v^2 \right) / 2, \quad \text{or:}$$

$$\lambda < \left(1 - \frac{\bar{\tau} + \underline{\tau}}{2} \right) \left(\gamma \Delta_t + \frac{B v^2}{\gamma \Delta_t} \right). \tag{20}$$

We first see that the *political influence of wealth* must not be too large, compared to the *aggregate welfare gain* from redistribution relative to laissez faire (net of the deadweight loss, which I am here abstracting from). Second, preexisting income inequality *raises the hurdle* that public policy must overcome, as the ex-ante benefit term Bv^2 is divided by $\gamma \Delta_t$. This effect impedes the adoption of more redistributive

[31] The required condition appears in Proposition 7. It is thus not inevitably the case that skill-biased technical progress leads to a retrenchment of redistributive institutions; the model allows for the reverse case, for steady-states that occur on the rising part of the T locus. The case on which I focus, however, appears to be the most relevant for recent trends, and in any case is the more robust, since: i) when multiple steady-states exist, there is always at least one the declining part; ii) in simple and plausible variants of the model, the T locus is decreasing throughout (see footnote 30).

institutions ($\tau = \bar{\tau}$) where they had not previously been in place, because of the greater divergence of interests that results over time from a more laissez-faire system ($\tau = \underline{\tau}$). Pushing in the other direction – namely, intensifying the demand for redistribution as inequality rises– are the effects of skewness and initial credit-constraints, reflected in the additive term $\gamma\Delta_t$. As a result of these offsetting forces, the right-hand side of (20) is U-shaped in $\gamma\Delta_t$. To focus on the long–run, let us now replace human capital inequality Δ_t with its asymptotic value under a technology γ and a constant policy τ –namely, by (11):

$$D(\tau,\gamma) \equiv \sqrt{\frac{w^2+\beta^2(1-\tau)^2v^2}{1-(\alpha+\beta\gamma(1-\tau))^2}}, \tag{21}$$

which is the long-run inequality in human capital resulting from a constant policy τ and technology γ. Given γ, the policy-inequality pair $(\bar{\tau}, D(\tau,\gamma))$ is thus a politico-economic steady state if:

$$\lambda < \left(1-\frac{\bar{\tau}+\underline{\tau}}{2}\right)\left(\gamma D(\tau,\gamma)+\frac{Bv^2}{\gamma D(\tau,\gamma)}\right) \equiv \bar{\lambda}(\gamma;B). \tag{22}$$

Conversely, the laissez-faire configuration $(\underline{\tau}, D(\underline{\tau},\gamma))$ is a politico-economic steady state given γ if:

$$\lambda > \left(1-\frac{\bar{\tau}+\underline{\tau}}{2}\right)\left(\gamma D(\underline{\tau},\gamma)+\frac{Bv^2}{\gamma D(\underline{\tau},\gamma)}\right) \equiv \underline{\lambda}(\gamma;B). \tag{23}$$

The two regimes coexist if and only if $\underline{\lambda}(\gamma;B) < \bar{\lambda}(\gamma;B)$, or:

$$\frac{\bar{\lambda}(\gamma;B)-\underline{\lambda}(\gamma;B)}{\gamma D(\underline{\tau},\gamma)-\gamma D(\bar{\tau},\gamma)} = \left(1-\frac{\bar{\tau}+\underline{\tau}}{2}\right)\left(\frac{Bv^2}{\gamma^2 D(\bar{\tau},\gamma)D(\underline{\tau},\gamma)}-1\right). \tag{24}$$

We thus obtain here the analogue, for a discrete policy choice, of Proposition 4: multiplicity requires that B be large enough compared to income inequality (and, in general, to $1/\eta$),

$$B > \left(\gamma^2/v^2\right)\cdot D(\bar{\tau},\gamma)\cdot D(\underline{\tau},\gamma) \equiv \underline{B}(\gamma), \tag{25}$$

and that the wealth bias λ be neither too high nor too low, given the technology $\gamma : \lambda \in \left[\underline{\lambda},\bar{\lambda}\right]$, defined by (22)-(23).[32] Now, furthermore, we shall see that (under appropriate conditions) the *skill bias* γ must also be neither too high nor too low, given λ. This result is illustrated in Figure 4.

Proposition 7 *Let $1/\eta = 0$ and $Bv^2 > \gamma_{\max}\cdot D(\underline{\tau},\gamma_{\max})$, where $\gamma_{\max} \equiv (1-\alpha)/\beta$. There exist two skill-bias thresholds $\underline{\gamma}(\lambda;B) < \bar{\gamma}(\lambda;B)$, both decreasing in λ and increasing in B, such that:*

[32] Note also that as B increases both $\underline{\lambda}$ and $\bar{\lambda}$ rise, but (24) shows that the interval $[\underline{\lambda},\bar{\lambda}]$ widens. When (25) does not hold, on the other hand, we have $\bar{\lambda} < \underline{\lambda}$. For $\lambda \notin [\bar{\lambda},\underline{\lambda}]$ there is a unique steady–state, but for $\lambda \in [\bar{\lambda},\underline{\lambda}]$ the economy can instead be shown to cycle between the two regimes, as in Gradstein and Justman (1997). This feature reflects the restriction of policy to a binary choice.

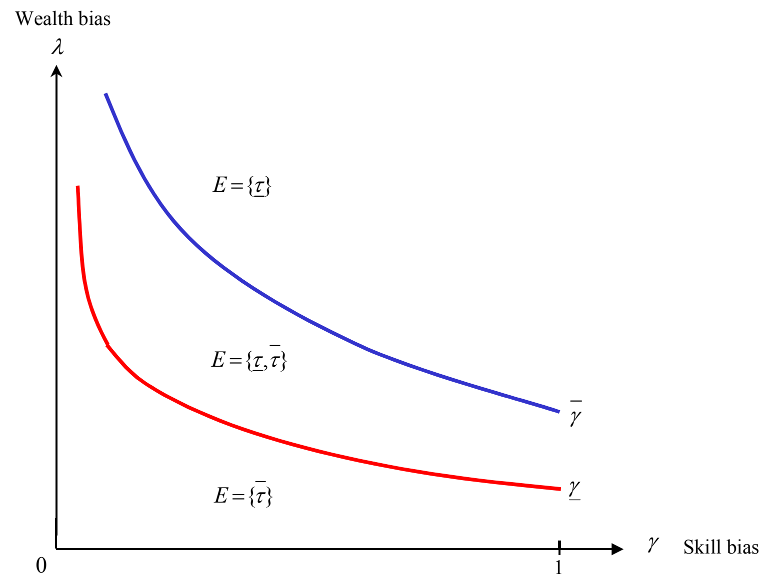

Figure 4: Technology, political influence, and the social contract. E denotes the set of stable steady-states, with $\bar{\tau}$ = "Welfare State" and $\underline{\tau}$= "Laissez Faire".

i) for $\gamma < \underline{\gamma}(\lambda; B)$, *the unique steady state corresponds to the welfare-state outcome* $(\bar{\tau}, D(\bar{\tau}, \gamma))$;

ii) for $\gamma \in \left[\underline{\gamma}(\lambda; B), \bar{\gamma}(\lambda; B)\right]$, *both* $(\bar{\tau}, D(\bar{\tau}, \gamma))$ *and* $(\underline{\tau}, D(\underline{\tau}, \gamma))$ *are stable steady states;*

iii) for $\gamma \in [\bar{\gamma}(\lambda; B), \gamma_{\max}]$, *the unique steady state is laissez-faire,* $(\underline{\tau}, D(\underline{\tau}, \gamma))$.

These results have a number of important implications.

First, they confirm that *the Welfare State becomes unsustainable* when technology becomes too skill-biased; and, conversely, that multiple social contracts can coexist only when γ is in some intermediate range.[33] We see here again at work the general insight that sources of heterogeneity that are predictable on the basis of of initial endowments –a greater variance of abilities, w^2, as discussed earlier, or greater skill bias γ, as here– push equilibrium institutions towards less redistribution.

Second, Proposition 7 also reveals interesting interactions between *the production and political "technologies".* As seen on Figure 4, in a country with relatively little wealth bias the welfare state is –for better of for worse– much more "immune" to skill-biased technical change than in one where λ is high. Similarly, a given change in the political system will have very different effects on redistributive institutions, depending on how skill-biased the technology is. Finally, the "surest way" to set out on a course of persistently high inequality and inefficiently regressive (or insufficiently progressive) institutions is to start out with

[33] Hassler et al. (2003) also show that the "welfare-state" equilibrium in their model no longer exists above a certain level of skill bias. The mechanism is quite different, however: it is the *anticipation* of a higher skill premium that causes more agents to invest in education –to the point where, ex-post, a majority of them end up with high incomes (the distribution is negatively skewed), and therefore oppose redistribution.

both a production structure that generates high wage inequality, and a political system marked by a high degree of bias. As demonstrated by Engerman and Sokoloff (1995), such were the initial conditions found in the plantation-based and natural-resource based colonies of Central and South America in the 16^{th} and 17^{th}centuries –in contrast to those of North America, where agriculture was not subject to significant increasing returns to scale, and initial institutions were much less oligarchic.

Third, our result can also be related to that of Acemoglu, Aghion and Violante (2001), who show that skill-biased technical progress may cause a decline in unionization. While their model is quite different, it shares the two key features emphasized in previous sections. First, relatively rich agents –namely skilled workers– are pivotal, in the sense that it is their willingness to leave or avoid the unionized sector that limits the extent of wage compression. Second, in making this mobility decision –voting with their feet– they trade off redistributive losses (unions redistribute towards unskilled workers, who are a majority in the unionized sector) against ex-ante efficiency benefits: unions provide insurance through wage-sharing and / or a safeguard against the "holdup" by firms of workers' specific human capital investments; even when they play no such role, leaving the unionized sector involves mobility costs. Consequently, when skill-biased technical change makes the interests of the two classes of workers too divergent, redistributive institutions –here, union participation– will decline. Moreover, this can happen inefficiently.[34]

B *Skills, Technology, and Income Inequality*

I now turn to the reverse mechanism and examine how inequality itself *feeds back* onto the nature of technical change, making γ endogenous. Recognizing that individuals do not produce in isolation, I model production interactions with a simple specialization structure where workers perform complementary tasks.[35] Final output is produced by competitive firms, using a continuum of differentiated intermediate inputs:

$$y_t = A_t \cdot \left(\int_0^{\infty} z_t(s) \cdot x_t(s)^{\frac{\sigma-1}{\sigma}} \, d\, s \right)^{\frac{\sigma}{\sigma-1}} , \ \sigma \geq 1, \tag{26}$$

where $x_t(s)$ denotes the quantity of input s, $z_t(s)$ an i.i.d. sectoral shock, and A_t a TFP parameter. Workers specialize in a single good, which they produce using their human capital and labor. Since they face downward-sloping demand curves each selects a different task, $s(i) = i$, and produces $x_t^i = k_t^i \, l_t^i$ units, where l_t^i is endogenously chosen. The unit price for his output is thus:

$$p_t^i = A_t^{\frac{\sigma-1}{\sigma}} \cdot z_t^i \cdot (k_t^i \, l_t^i / y_t)^{-\frac{1}{\sigma}} \ . \tag{27}$$

[34] Relatedly, note from Figure 4 that a minor change in γ can trigger a significant decline in redistribution from $\bar{\tau}$ to $\underline{\tau}$, and recall from Proposition 5 that the latter can easily lead to lower aggregate growth. The same is clearly true for average welfare, e.g. when $1/\eta = 0$.

[35] Building on those in Bénabou (1996) and Tamura (1992), themselves based on Romer (1987).

The corresponding hourly wages are $\omega_t^i = p_t^i\, k_t^i$, and the resulting incomes

$$y_t^i = \omega_t^i\, l_t = z_t^i \cdot \left(k_t^i\, l_t^i\right)^{\frac{\sigma-1}{\sigma}} \times A_t^{\frac{\sigma-1}{\sigma}} \left(y_t\right)^{\frac{1}{\sigma}} \equiv \tilde{A}_t \cdot z_t^i \cdot \left(k_t^i\right)^{\gamma} (l_t^i)^{\delta}. \tag{28}$$

This earnings function is exactly the same as in previous sections (see (1)), with

$$\gamma = \delta \equiv \frac{\sigma - 1}{\sigma}, \tag{29}$$

except for the extra TFP factor $\tilde{A}_t \equiv A_t^{\frac{\sigma-1}{\sigma}} \left(y_t\right)^{\frac{1}{\sigma}}$, which acts as a shift in the mean of the productivity shocks z_t^i. While $\tilde{A}_t$ varies endogenously with the economy's state variables (m_t, Δ_t^2), individual workers and voters take it as given in their decisions over (l_t^i, c_t^i) and their votes over τ_t.[36] Consequently, the entire analysis of earlier sections still applies, with the simple substitution of $\tilde{A}_t \cdot z_t^i$ wherever z_t^i previously appeared. Conditional on γ, distributional dynamics and the political equilibrium thus remain essentially unchanged, and so do the corresponding $\Delta = D(\tau, \gamma)$ and $\tau = T(\gamma\Delta)$ loci.

I now consider firms. Recall that in equilibrium all workers supply the same effort $l_t^i = l_t$ and the distribution of human capital remains lognormal, $\ln k_t^i \sim \mathcal{N}(m_t, \Delta_t^2)$. The output of a representative firm is thus:

$$y_t = A_t \cdot l_t \cdot \left(\int_0^1 \left(k_t^i\right)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} = A_t \cdot l_t \cdot e^{-\Delta_t^2/2\sigma} \cdot \left(\int_0^1 k_t^i\, di \right). \tag{30}$$

Keeping average human capital constant, the loss $e^{-\Delta_t^2/2\sigma}$ makes apparent the productivity costs imposed by (excessive) *heterogeneity of the labor force:* poorly educated, insufficiently skilled production and clerical workers drag down the productivity of engineers, managers, scientists, etc. We also see that a production technology with greater substitutability between the tasks performed by different types of workers reduces these costs of skill disparities (Bénabou (1996), Grossman and Maggi (2000)). Indeed, this greater *flexibility* allows firms to more easily substitute towards the more productive workers, and conversely reduce their dependence on low-skill labor. This may be achieved by internal retooling, reorganization, or by outsourcing certain activities to competitive subcontractors.[37] One can also think of a higher σ as a more discriminating search technology, resulting in more assortative matching between workers –that is, in a more *segregated* production structure (Kremer and Maskin (1996), (2003)).[38]

Naturally, production processes with less complementarity between workers of different skills result in greater inequality of wages and incomes, as they have the effect of *uncoupling* their marginal products:

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[36] Note again the role of the overlapping-generations structure with "imperfect" altruism in simplifying the voting problem. Observe also that τ_t can now, as claimed earlier, be interpreted as the extent of *wage income compression,* i.e. the degree of progressivity in the mapping (defined by (6)) from workers' true marginal revenue products y_t^i (given by (28)) to the labor earning they actually receive, $\hat{y}_t^i$.

[37] For evidence on organizational change, see for instance Caroli and Van Reenen (1999).

[38] When labor supply is endogenous, $1/\eta > 0$, a higher σ also induces workers to increase their labor supply, as they face a less elastic demand curve: by Proposition 1, $l_t = \chi\, (1 - \tau_t)^{1/\eta}$, with now $\gamma = (\sigma - 1)/\sigma$. This effect is independent of any issues of skill heterogeneity or wage inequality, however.

$$\operatorname{Var}\left[\ln y_t^i\right] = \left(\frac{\sigma_t - 1}{\sigma_t}\right)^2 \Delta_t^2 = \gamma_t^2 \Delta_t^2. \tag{31}$$

C *Technological Choice and Endogenous Flexibility*

More flexible technologies and production processes require costly investments or reorganizations. Moreover, their benefits to an individual firm are endogenous even in the short run (i.e., given the skill composition of the labor force), as they depend on the decisions of other firms, which affect the wage structure.

I therefore now model firms' choices of technology or organizational form, proposing a new and very simple formulation that highlights the roles of heterogeneity and flexibility. In every period, firms have access to a menu of potential technologies with *different elasticities of substitution* $\sigma \in [1, +\infty)$ and associated costs $c(\sigma)$; the latter result in a TFP factor $A(\sigma) = e^{-c(\sigma)}$, with $c' > 0$ and $c'' > 0$.[39] Given the distribution of workers' human capital $\ln k_t^i \sim \mathcal{N}(m, \Delta_t^2)$ and the technology σ_t used by its competitors, each firm chooses its own technology $\hat{\sigma}$ as a best response. This results in a marginal cost of

$$A(\hat{\sigma})^{-1} \left(\int_0^1 \left(z_t^i\right)^{\hat{\sigma}} \left(p_t^i\right)^{1-\hat{\sigma}} di \right)^{\frac{1}{1-\hat{\sigma}}}. \tag{32}$$

Substituting from (27) for the equilibrium input prices p_t^i, and normalizing by the other firms' marginal cost (see the proof of Proposition 8), the firm's relative marginal cost is equal to:

$$mc(\hat{\sigma}|\sigma_t) = \left(\frac{A(\sigma_t)}{A(\hat{\sigma})}\right) \cdot \left(\int_0^1 \left(k_t^i\right)^{\frac{1-\hat{\sigma}}{\sigma_t}} di \right)^{\frac{1}{1-\hat{\sigma}}} \cdot \left(\int_0^1 \left(k_t^i\right)^{\frac{1-\sigma_t}{\sigma_t}} di \right)^{\frac{-1}{1-\sigma_t}},$$

or:

$$mc(\hat{\sigma}|\sigma_t) = \exp\left[c(\hat{\sigma}) - c(\sigma_t) + \frac{\Delta_t^2}{2}\left(\frac{\sigma_t - \hat{\sigma}}{\sigma_t^2}\right)\right]. \tag{33}$$

The first-order condition for this convex minimization problem is

$$c'(\hat{\sigma}) = \frac{\Delta_t^2}{2\sigma_t^2}. \tag{34}$$

Intuitively, the marginal benefit of flexibility rises with the variability of skills in the labor force, but decreases with the degree to which other firms choose technologies that allow them to more easily substitute toward better workers, since in doing so they drive up the skill premium.

[39] I thus abstract here from the intertemporal (investment) aspects of innovation that would be part of a more complete (but also more complicated) model of technological change; see, e.g., Acemoglu (1998), Kiley (1999), Lloyd-Ellis (1999), or Aghion (2002).

Proposition 8 *There is a unique symmetric equilibrium in technology choice. The more heterogenous the workforce, the more flexible and skill-biased the technology used by firms:* $\sigma_t = \sigma^*(\Delta_t)$ *is the solution to* $c'(\sigma^*) = \Delta^2/2(\sigma^*)^2$, *with* $0 < \partial \ln \sigma^*/\partial \ln \Delta < 1$.

This result has several interesting implications.

A first one is the *magnification of wage inequality:* the return to human capital $\partial \ln \omega_t^i/\partial \ln k_t^i = (\sigma_t - 1)/\sigma_t$ is higher where the labor force is more heterogenous, further amplifying wage differentials across educational levels. This simple prediction could be tested empirically across countries and / or time periods.[40]

A second implication is the potential for *"immiserizing technological choices".* Proposition 8 states that σ increases with Δ; conversely, because of credit constraints, human capital heterogeneity itself rises over time with $\gamma = (\sigma - 1)/\sigma$, and in the long-run $\Delta = D(\tau, \gamma)$, which is increasing in γ. Could these two mechanisms reinforce each other to the point of resulting in multiple steady states *even under a fixed policy* –whether activist or laissez-faire– and even though, once again, there are no non-convexities in the model? The idea is that a high degree of skill bias results in very low wages for unskilled workers, severely limiting the extent to which they can invest in human capital (for themselves or their children). This, in turn, leads firms to again choose a very flexible, skill-biased technology in the next period, and so on. Conversely, a less skilled-biased technology and a less dispersed distribution of human wealth could be self-sustaining. To examine this possibility, note first that:

$$\frac{\partial \ln \sigma^*}{\partial \ln \Delta} = \left(1 + \frac{1}{2}\frac{c''(\sigma_t)}{c'(\sigma_t)}\right)^{-1} < 1 \tag{35}$$

by Proposition 8, while (21) yields

$$\frac{\partial \ln D(\tau, \gamma)}{\partial \ln \sigma} = \frac{\beta(1-\gamma)(1-\tau)(\alpha + \beta\gamma(1-\tau))}{1 - (\alpha + \beta\gamma(1-\tau))^2} \tag{36}$$

where, as usual, $\gamma = (\sigma - 1)/\sigma$. If the product of these two derivatives is everywhere less than 1, there is a unique equilibrium. If it exceeds 1 for some value of σ, on the other hand, there may be multiplicity. It is easily verified that $\partial D(\tau, \gamma)/\partial \ln \sigma < 1$ if and only if

$$(\alpha + \beta\gamma(1-\tau))(\alpha + \beta(1-\tau)) < 1. \tag{37}$$

The first term is always less than one (or else inequality explodes; moreover, this can never occur when τ is

[40] Kremer and Maskin (1996) present evidence for a related intervening mechanism (similar to $\partial\sigma^*/\partial\Delta > 0$ in this model), although not for how educational returns and wage inequality are ultimately affected. They show that in US states characterized by greater human capital inequality, there is more segregation of workers by skills (the ratio of within- to between-plant skill dispersion is lower).

endogenously chosen), but the second need not be, especially if $\tau < 0$. We can thus conclude that the kind of *"technology-inequality trap"* described above becomes a real possibility under *regressive or insufficiently progressive* policies. In particular, education systems that result in significant resource disparities between students, such as private financing or local (property-tax based) school funding as in the United States, are fertile ground for the joint emergence of highly skill-biased production processes and a persistently skewed skill distribution. Furthermore, as we shall see below, endogenizing τ only increases the likelihood of such outcomes, since the degree of redistribution tends to fall with inequality.

A third point is that even under the less extreme conditions where no such trap exists, firms' decisions involve a *dynamic externality* that tends to result in *excessively skill-biased* or flexible technologies. Indeed, each takes the distribution of skills it faces as given but neglects the effects of its own flexibility on workers' human capital investments, and therefore on subsequent distributions. More specifically, while a marginal change in σ_t has only second-order effects on the current production costs faced by firms, it has three first-order effects on growth.[41] First, a lower σ_t would reduce current income inequality $\gamma_t \Delta_t$, which is growth-enhancing given the presence of credit constraints. This would in turn lower the skill disparities Δ_{t+k} that firms will face in the future, as well as the costs $c\left(\sigma^*(\Delta_{t+k})\right)$ they will bear to adapt to this heterogeneity. Although $\gamma_t = (\sigma_t - 1)/\sigma_t$ also affects in a somewhat complex way the concavity of educational investment (where it interacts with α, β and τ_t), it is easy to identify cases where growth *in every period* would be higher if firms collectively chose less skill-biased technologies.

For instance, let $\alpha = 0$, $\beta = 1$, and $1/\eta = 0$ (inelastic labor supply), and fix any constant policy τ; the interactions of technology choice and policy decisions will be examined in the next section. In the resulting steady state, the degree of flexibility and the dispersion in skills are given by the two equations $\sigma_\infty = \sigma^*(\Delta_\infty)$ and $\Delta_\infty = D(\tau, \gamma_\infty)$, where $\gamma_\infty \equiv (\sigma_\infty - 1)/\sigma_\infty$.[42] The corresponding asymptotic growth rate is computed in the appendix, and equals:

$$g_\infty = \ln \kappa + \ln s - c(\sigma_\infty) - \frac{D(\tau, \gamma_\infty)^2}{2\sigma_\infty}. \tag{38}$$

A marginal reduction in σ from its equilibrium value, if it were permanently implemented by all firms, would then increase steady-state growth, since:

$$\left.\frac{\partial g_\infty}{\partial \sigma}\right|_{\sigma=\sigma_\infty} = -c'\left(\sigma_\infty\right) + \frac{\Delta_\infty^2}{2\sigma_\infty^2} - \frac{1}{2\sigma_\infty} \cdot \left.\frac{\partial D^2(\tau, \gamma_\infty)}{\partial \sigma}\right|_{\sigma=\sigma_\infty} = -\frac{1}{2\sigma_\infty^3} \cdot \frac{\partial D^2(\tau, \gamma_\infty)}{\partial \gamma} < 0. \tag{39}$$

In this expression the first two terms cancel out by the first-order condition (34), while the last one reflects

[41] As explained in footnote 38, when $1/\eta > 0$ a higher σ_t also raises the return to labor supply $\delta_t = (\sigma_t - 1)/\sigma_t$, inducing all agents to work more.

[42] I assume here that (37) holds, so that this steady-state is unique (given τ), although this is inessential to the argument.

the dynamic externality. The above result holds more generally for any equilibrium path that is either near the steady state, or such that σ_t converges to its long-run value from above (see the appendix).

Inefficient choices of technology or firm organization arise in a number of models where market imperfections create an excessive role for the distribution of financial or human wealth to shape the structure of production, with the result of exacerbating inequality and making it more persistent. In Banerjee and Newman (1993) and Newman and Legros (1998), for instance, the moral-hazard problem affecting entrepreneurship combines with an unequal wealth distribution in forcing too many agents to work for low wages in large firms, rather than setting up their own. In Vindigni (2002) an extreme example of the technology trap studied above occurs, as firms' decisions (choosing the arrival rate of exogenously skill-biased innovations) can permanently confine some dynasties of workers below the fixed income threshold required to invest in human capital.[43] In Grossman (2004), a high variance of human capital in the labor force increases the incentives of the most skilled agents to work in sectors where individual productivity is observable, rather than in those where output is team-determined; because they fail to internalize the spillovers they would have on team productivity, the resulting occupational segregation is inefficiently high.

IV Endogenous Institutions and Endogenous Technology

Combining the main mechanisms analyzed in previous sections yields a model where the distribution of human capital, the technologies used by firms and the policy implemented by the state are all endogenous –as they are in reality. The dynamical system governing the economy's evolution remains recursive:

$$\begin{cases} \gamma_t &= \Gamma(\Delta_t) \\ \tau_t &= T(\Delta_t \gamma_t) \\ \Delta_{t+1} &= \mathcal{D}(\Delta_t, \tau_t; \gamma_t) \end{cases}, \tag{40}$$

where $\Gamma(\Delta) \equiv (\sigma^*(\Delta) - 1)/\sigma^*(\Delta)$ represents the technology outcome given by Proposition 8, $T(\gamma\Delta)$ the policy outcome given by Proposition 3, and $\mathcal{D}(\Delta, \tau, \gamma)$ the transmission of human capital inequality given in Proposition 2. The resulting aggregate growth rate, $\ln(y_{t+1}/y_t) = g(\tau_t, \Delta_t, \gamma_t)$, follows from Proposition 2. Finally, steady states are solutions to the fixed-point equation

$$\Delta = \mathcal{D}(\Delta, T(\Delta; \Gamma(\Delta)), \Gamma(\Delta)). \tag{41}$$

[43] A more benign form of multiplicity (with greater wage inequality now going together with more, rather than less, total human capital) occurs in Acemoglu (1998). In his model, a relative abundance of skilled workers makes it more profitable for firms to develop skill-biased technologies; this then raises the wage premium, encouraging more workers to become skilled.

This structure makes clear the presence of important *multiplier effects:* a transitory shock affecting inequality (e.g., more idiosyncratic uncertainty v^2) or the political system (a higher λ) will be amplified through technology decisions, the policy choice, and the intergenerational transmission mechanism, and may thus have considerable long-term consequences.[44] Most importantly, in accounting for changes in inequality *one can no longer treat technological and institutional factors as separate,* competing explanations: both are jointly determined, and complementary. The model thus shows how, in the words of Freeman (1995), one needs to think of *"the Welfare State as a system".*

To demonstrate these points I shall assume from here on a piecewise-linear technological frontier. Flexibility is free up to σ_L, then has a marginal cost of $M > 0$, up to a maximum level $\sigma_H > \sigma_L$:

$$c(\sigma) = \begin{cases} 0 & \text{for} \quad \sigma < \sigma_L \\ M(\sigma - \sigma_L) & \text{for} \quad \sigma \in [\sigma_L, \sigma_H] \\ +\infty & \text{for} \quad \sigma > \sigma_H \end{cases} . \tag{42}$$

I will denote $\gamma_i = (\sigma_i - 1)/\sigma_i$, $i \in \{L, H\}$. The analogue of Proposition 8 in this case is very simple, as the first order condition in a symmetric equilibrium involves the comparison:

$$M \gtrless \frac{\Delta_t^2}{2\sigma_t^2}. \tag{43}$$

The unique symmetric outcome is thus $\sigma_t = \sigma_L$ when $\Delta_t^2/2M < \sigma_L^2$, and $\sigma_t = \sigma_H$ when $\Delta_t^2/2M > \sigma_H^2$. When $\Delta_t^2/2M \in (\sigma_L^2, \sigma_H^2)$, on the other hand, firms mix between σ_L and σ_H, in proportions such that the resulting factor prices make each one indifferent; this equilibrium will be denoted σ_{LH}.[45] Focussing now on technology-inequality steady states, for any $\tau \leq 1$ and $\sigma \geq 1$ the *marginal benefit of flexibility* (right-hand-side of (43)) equals

$$R(\tau, \sigma) \equiv \frac{D(\tau; (\sigma - 1)/\sigma)^2}{2\sigma^2},$$

where $D(\tau, \gamma)$ is the asymptotic variance under the policy τ and return to skill γ, given by (21). Thus, under any time-invariant policy τ, whether exogenous or endogenous:

- For $M > \max\{R(\tau, \sigma_L), R(\tau, \sigma_H)\}$, the unique technological steady state is σ_L;
- For $M < \min\{R(\tau, \sigma_L), R(\tau, \sigma_H)\}$, it is σ_H;
- If $R(\tau, \sigma_L) > R(\tau, \sigma_H)$, then for $M \in [R(\tau, \sigma_H), R(\tau, \sigma_L)]$ it is the mixed-strategy outcome σ_{LH};
- If $R(\tau, \sigma_L) < R(\tau, \sigma_H)$, then for $M \in [R(\tau, \sigma_L), R(\tau, \sigma_H)]$ there are three technological steady states:

[44] The long-run multiplier for any shock to the $\mathcal{D}$ function (e.g., a change in w^2) is $\mu \equiv \left(1 - \mathcal{D}_1 - \mathcal{D}_2\left(\frac{\partial T}{\partial \Delta} + \frac{\partial T}{\partial \Gamma}\frac{\partial \Gamma}{\partial \Delta}\right) - \mathcal{D}_3 \frac{\partial \Gamma}{\partial \Delta}\right)^{-1}$. Similarly, the long-run effects on inequality of a shock to the T function (e.g., a change in λ) its is $\mu \cdot \mathcal{D}_2(\partial T/\partial \lambda)$.

[45] It is not necessary to provide here the full characterization of this mixed-strategy equilibrium.

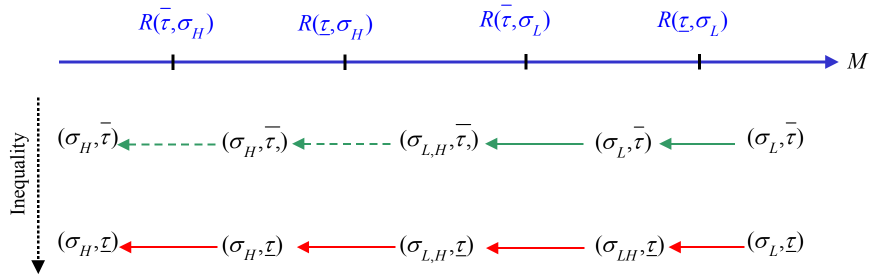

Figure 5: The response of technology and policy to a decline in the cost of flexibility (case (i)). Under each range of M appears the unique (σ, τ) such that $(\sigma, \Delta = D(\tau; 1 - 1/\sigma))$ is a stable steady state given τ and M. The subset reached via solid lines corresponds to the stable steady-states in (σ, Δ, τ) jointly, when policy is endogenous as well.

σ_L, σ_H, and σ_{LH}; the first two are stable, the third one unstable.

Furthermore, since $R(\tau, \sigma)$ is decreasing in τ, we have:

Proposition 9 *More skill-biased technologies appear first in, and less skill biased technologies disappear first from, countries that have less redistributive fiscal, educational or labor market institutions. For any* $M > 0$:

1) If σ_H *is a steady state equilibrium technology under a constant redistributive policy* τ, *this remains true under any less progressive policy* $\tau' < \tau$.

2) If σ_L *is a steady state equilibrium technology under a constant redistributive policy* τ', *this remains true under any more progressive policy* $\tau < \tau'$.

These results are illustrated in Figures 5 and 6 for two cases where: i) $R(\underline{\tau}, \sigma_H) < R(\bar{\tau}, \sigma_L)$, implying that for each M there is a unique technology compatible in the long-run with each policy $\tau \in \{\underline{\tau}, \bar{\tau}\}$;[46] ii) $R(\underline{\tau}, \sigma_L) < R(\bar{\tau}, \sigma_H)$, implying that for either policy $\tau \in \{\underline{\tau}, \bar{\tau}\}$ there is a range of M's where multiple technologies are sustainable. The message is essentially the same in both cases, showing how a *world-wide shift* in the set of feasible technologies can result in *different evolutions* of both production processes and the skill premium across countries. In particular, the model can help explain why skill-biased technical change and reorganization occurred first, and to a greater extent, in the United States compared to Europe –and within Europe, more so in England than on the Continent.[47]

[46] For instance, under condition (37), $\partial \ln \Delta_\infty / \partial \ln \sigma < 1$, so $R(\underline{\tau}, \sigma_H) < R(\underline{\tau}, \sigma_L)$ provided σ_H and σ_L are close enough. If $\underline{\tau}$ and $\bar{\tau}$ are also not too different, then $R(\bar{\tau}, \sigma) \precsim R(\underline{\tau}, \sigma)$ for $\sigma = \sigma_H, \sigma_L$, so the thresholds rank as illustrated on Figure 5.

[47] Acemoglu (2003) proposes a different mechanism, based on imperfectly competitive labor markets, through which the wage-compression policies of continental European countries may have caused technological progress there to be less skill-biased than in the United States. In his model, a binding minimum wage makes low-skill workers' compensation a fixed price, whereas for high-skill workers the binding constraint for the firm is rent-sharing (due to search market frictions), which acts as a tax on productivity improvements. As a result, firms in high minimum-wage countries have greater incentives to invest in technologies that are complementary to low-skill labor than high-skill labor. In both Acemoglu's and the present model, the effects of policy on technology are indirect, operating through either the distribution of skills or equilibrium wages. In

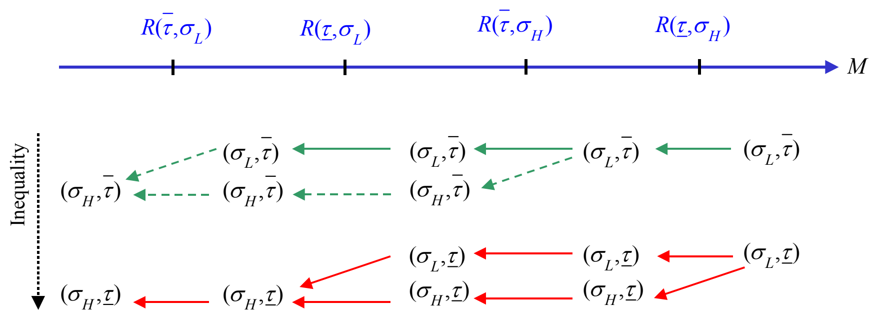

Figure 6: The response of technology and policy to a decline in the cost of flexibility (case (ii)). Under each range of M appear the values of (σ,τ) such that $(\sigma,\Delta = D(\tau;1-1/\sigma))$ is a stable steady state given τ and M. The subset reached via solid lines corresponds to the stable steady-states in (σ,Δ,τ) jointly, when policy is endogenous as well.

Indeed, consider two countries, C_1 and C_2, that are initially identical in all respects, including both using the technology σ_L, except that one is in a laissez-faire equilibrium, $\tau = \underline{\tau}$, and the other in a welfare state, $\tau = \bar{\tau}$. Suppose now that the technological frontier gradually flattens (M declines), meaning that flexibility becomes cheaper to achieve. As shown on Figures 5-6, the more skill-biased technology σ_H becomes (all or part of) another feasible equilibrium in C_1 before it does in C_2; similarly, σ_L first ceases to be viable (by itself or as part of a mixed equilibrium) in the laissez-faire country, while it is still sustainable in the more redistributive one.

Going further, there are in fact *reciprocal interactions* between the economy's *technology response* and *policy response* to shocks. Proposition 9 and Figures 5-6 show that feasible new technologies are not implemented unless institutions are sufficiently inegalitarian. But, conversely, the occurrence of technical change alters these same institutions, as seen in Proposition 7. Indeed, suppose that:

$$\underline{\lambda}(\gamma_L;B) < \lambda < \bar{\lambda}(\gamma_L;B), \tag{44}$$

where $\bar{\lambda}$ and $\underline{\lambda}$ were defined in (22)-(23). These inequalities imply that: i) under the technology σ_L, both social contracts $\underline{\tau}$ and $\bar{\tau}$ are political steady states; ii) under $\sigma_H, \bar{\tau}$ is a political steady state, while $\underline{\tau}$ is one if and only if we also have $\lambda < \bar{\lambda}(\gamma_H;B)$.

When this last inequality holds, the set of stable politico-economico-technological steady states (with endogenous τ, Δ and σ) is the same as described on Figures 5-6. When $\lambda > \bar{\lambda}(\gamma_H;B)$, however, the more redistributive social contract $\bar{\tau}$ is not *politically* sustainable under the amount of inequality that results, in the long run, from the technology σ_H. Therefore one must remove from the set of steady states on each figure the "branches" corresponding to this outcome; these are indicated by the dashed lines. The

Krusell and Rios-Rull (1996), by contrast, agents with different vintages of human capital vote directly on whether or not to allow the adoption of new technologies by firms.

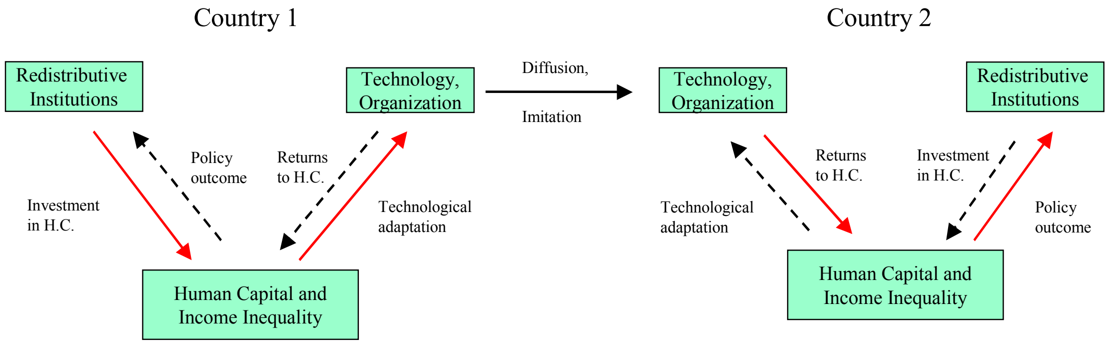

Figure 7: International spillovers between social contracts

remaining solid lines then indicate that *only certain politico-technological configurations* can be observed in the long run: a) for low values of M, e.g. for $M < R(\bar{\tau}, \sigma_L)$ on the first figure, the only feasible social contract is $\underline{\tau}$, together with the technology σ_H; b) on the second figure, for $M \in (R(\bar{\tau}, \sigma_L), R(\underline{\tau}, \sigma_L))$ only the egalitarian social contract and the egalitarian technology, or the inegalitarian social contract and inegalitarian technology, are mutually compatible.

V Exporting Inequality: Spillovers Between Social Contracts

The model also allows us to think about spillovers between national policies or institutions, operating via technological and organizational diffusion. The basic idea is illustrated in Figure 7, which shows how the social contract in Country 2 can, over time, be affected by technological or even purely political shifts in Country 1, propagated along the channels indicated by the solid lines on the diagram.

As seen in the previous section, firms operating in countries with more laissez-faire fiscal, educational or labor market policies have greater incentives to develop and adopt low-complementarity production processes. Suppose now that the cost of imitating, adapting or copying a more flexible technology or organizational form, once it has been developed and implemented elsewhere, is lower than the cost of innovation; in terms of the model, it is $m < M$. This lower marginal cost may for instance reflect, as in Acemoglu (1998), an imperfect international enforcement of property rights over technological or organizational innovations. As we shall see, redistributive institutions in one country will then be significantly affected, perhaps even completely undermined, by technological or political changes occurring in another.[48]

[48] As mentioned earlier I abstract here from international trade, which could be yet another channel of transmission. See Grossman and Maggi (2000), Grossman (2004) or Thoenig and Verdier (2003) for papers that study the effects of trade openness on technical and organizational change, although not their political economy implications.

A *A Shift in One Country's Technological Frontier*

I shall focus here on parameter configurations that satisfy the following conditions:

$$\max\left\{\underline{\lambda}(\gamma_L;B),\bar{\lambda}(\gamma_H;B)\right\} \quad < \quad \lambda<\bar{\lambda}(\gamma_L;B), \tag{45}$$

$$\max\left\{R(\underline{\tau},\sigma_L),R(\underline{\tau},\sigma_H)\right\} \quad < \quad M, \tag{46}$$

$$m \quad < \quad R(\bar{\tau},\sigma_L)<M'<\min\left\{R(\underline{\tau},\sigma_L),R(\underline{\tau},\sigma_H)\right\}, \tag{47}$$

which imply in particular that $M>M'>m$. As shown as part of Proposition 10 below, these conditions also ensure that the technology σ_L allows for both social contracts $\underline{\tau}$ and $\bar{\tau}$, and conversely that σ_L is an equilibrium technology under both social contracts (no firm wants to switch to σ_H).

Proposition 10 *Assume that conditions (45)–(47) are satisfied, and consider two countries, C_1 and C_2, that both start in steady state, with the same technology σ_L. Suppose now that the cost of flexibility in country C_1 declines from M to M'.*
1) If both C_1 and C_2 were initially in the more egalitarian of the two regimes compatible with σ_L nothing happens, in the sense that $(\bar{\tau},\gamma_L,D(\bar{\tau},\gamma_L))$ remains a stable steady state for both countries.
2) If C_1 was initially in the more inegalitarian regime $(\underline{\tau},\gamma_L,D(\underline{\tau},\gamma_L))$, the unique long run outcome is for both countries to switch to the technology σ_H, and for country C_2 to also adopt the more unequal social contract $\underline{\tau}$: the unique steady state for the two countries is now $(\underline{\tau},\gamma_H,D(\underline{\tau},\gamma_H))$.

The intuition is as follows. Even as M declines to M', firms faced with the skill distribution $D(\bar{\tau},\gamma_L)$ resulting from $\bar{\tau}$ do not find it profitable to switch technology. Given the higher dispersion $D(\underline{\tau},\gamma_L)$ that prevails under $\underline{\tau}$, however, if country C_1 starts in this regime all firms there will eventually switch to technology σ_H.[49] Next, given the lower cost of flexibility m to which firms in C_2 now have access through imitation, σ_L is no longer viable there even under $\bar{\tau}$. And, in turn, with the higher income inequality that results in the long run from technology σ_H, the only politically sustainable social contract is $\underline{\tau}$.

These results make clear how technological change (a shift in the frontier) has significant effects only when it is *mediated* through specific institutions –namely, which social contract C_1 had adopted; and, conversely, how under such conditions it will then affect institutions in other countries, namely here in C_2.

B *A Shift in One Country's Political Institutions*

I consider now a second scenario, namely the transmission of *a political shock.* Having seen earlier how the mere fact of being in different institutional steady states (say, for historical reasons) can lead to

[49] I leave aside the dynamics here, but they are straightforward: since (45) implies that (25) holds for $\gamma=\gamma_L$, γ_H, we always operate on the portion of the $T(\gamma\Delta)$ curve where increases in inequality imply decreases in the tax rate.

very different technological trajectories, I shall assume here that C_1 and C_2 both start in the egalitarian steady state, $(\bar{\tau}, \gamma_L, D(\bar{\tau}, \gamma_L))$, with the same technology σ_L. Let C_1 now experience an increase in the political influence of wealth, from λ to λ'. This may reflect a rising importance of *lobbying and campaign contributions*, an exogenous *decline in unionization,* or a lower *electoral turnout* by the poor. It may even simply represent the political outcome during a particular period in which the electorate stochastically shifted to the right.[50] I shall assume here the following conditions:

$$\bar{\lambda}(\gamma_H; B) \quad < \quad \lambda < \bar{\lambda}(\gamma_L; B) < \lambda', \tag{48}$$

$$m \quad < \quad R(\bar{\tau}, \sigma_L) < M < \min\{R(\underline{\tau}, \sigma_L), R(\underline{\tau}, \sigma_H)\}. \tag{49}$$

Proposition 11 *Assume that conditions (48)–(49) are satisfied. Consider two countries, C_1 and C_2, that both start in the egalitarian steady state, $(\bar{\tau}, \gamma_L,\ D(\bar{\tau}, \gamma_L))$, with the same technology σ_L. Suppose now that the political influence of wealth in country C_1 rises from λ to λ'. The unique long run outcome is for both countries to switch to the technology σ_H and the more unequal social contract $\underline{\tau}$, thus ending up at the steady state $(\underline{\tau}, \gamma_H, D(\underline{\tau}, \gamma_H))$.*

As a result of the initial political shift, redistribution τ_1 (fiscal, educational, or via labor-market institutions) in country C_1 declines. This leads over time to a rise in human capital inequality Δ_1, to which firms respond by adopting more flexible, wage-disequalizing technologies, switching from σ_L to σ_H and further precipitating the shift from $\bar{\tau}$ to $\underline{\tau}$. Their counterparts in C_2, which would not have developed such technologies by themselves, now find it profitable to copy them from C_1. This results in a rise in income inequality $\gamma_2 \Delta_2$ in C_2 (and, over time, in human-capital inequality Δ_2 itself) that ultimately leads to the unravelling of the Welfare State in that country as well.

VI Concluding Comments

This paper offers a new, unified model to analyze the reciprocal interactions between the distribution of human wealth, technology, and redistributive institutions. It identifies in particular certain core mechanisms that allow alternative societal models to persist, as well as powerful forces pushing towards uniformization. Key among the former is the interplay of imperfections in asset markets and in the political system that can lead to multiple steady states where inequality and redistribution are negatively correlated. Among the latter is skill-biased technical change, which can potentially lead to the unravelling of the Welfare State. When technological or organizational form is endogenous, moreover, firms respond to greater human capital heterogeneity with more flexible technologies, further exacerbating income inequality. The possibility

[50] Indeed, the political shock need not be permanent, provided the speed at which λ reverts to its previous value is low enough, relative to those of human capital adjustment and technological or organizational evolution.

for firms in different countries to thus choose technologies adapted to the local labor force can also make it easier to sustain multiple social models. The international diffusion of technology, however, implies that the more flexible, skill-biased technologies profitably developed in nations with greater inequality and less redistributive institutions may then be imitated by firms in other countries, thereby triggering a "chain reaction" that moves the whole system towards a common outcome that is more inegalitarian –technologically, economically, and politically speaking. Such international spillovers between national social contracts are important concerns in the debate over globalization, and warrant further research.

Appendix

Proofs of Propositions 1-5. See Bénabou (2000); I shall only provide here:

(i) the formula for the break-even income level $\tilde{y}_t$ where $\hat{y}_t^i = y_t^i$,

$$\ln \tilde{y}_t = \gamma m_t + \delta \ln l_t + (2-\tau_t)\gamma^2 \Delta_t^2/2 \; + (1-\tau_t)v^2/2; \tag{A.1}$$

(ii) the laws of motion for (m_t, Δ_t^2) that underlie Proposition 2,

$$m_{t+1} = (\alpha + \beta\gamma)\, m_t + \beta\delta \ln l_t + \beta\, \tau_t\, (2-\tau_t)\, (\gamma^2\Delta_t^2 + v^2)/2 + \ln\left(\kappa s^\beta\right) - (w^2 + \beta v^2)/2 \tag{A.2}$$

$$\Delta_{t+1}^2 = (\alpha + \beta\gamma(1-\tau_t))^2\, \Delta_t^2 + \beta^2(1-\tau_t)^2\, v^2 + w^2; \tag{A.3}$$

(iii) and the formula for each agent's intertemporal welfare that underlies Proposition 3: under a rate of redistribution τ_t,

$$U_t^i = \bar{u}_t + A(\tau_t)(\ln k_t^i - m_t) + C(\tau_t) - (1-\rho+\rho\beta)(1-\tau_t)^2 \left(\gamma^2\Delta_t^2 + Bv^2\right)/2, \tag{A.4}$$

where $\bar{u}_t$ is independent of the policy τ_t, $B \equiv a + \rho(1-a)(1-\beta)$ was defined in (14) and:

$$A(\tau) \equiv \rho\alpha + (1-\rho+\rho\beta)\gamma(1-\tau), \tag{A.5}$$

$$C(\tau) \equiv (1-\rho)(\delta \ln l(\tau) - l(\tau)^\eta) + \rho\beta\delta \ln l(\tau), \tag{A.6}$$

The first-order condition (15) readily follows. ■

Proof of Proposition 7. Because $D(\tau,\gamma)$ is increasing in γ for all τ the functions $\bar{\lambda}(\gamma; B)$ and $\underline{\lambda}(\gamma; B)$ are both U-shaped in γ, and minimized at the point where $\gamma D(\tau,\gamma) = v\sqrt{B}$, for $\tau = \bar{\tau}$, $\underline{\tau}$ respectively. Furthermore, the minimum of $\bar{\lambda}(\gamma; B)$ occurs to the right of that of $\underline{\lambda}(\gamma; B)$. Under the assumption that $v\sqrt{B} > \gamma_{\max}\, D(\underline{\tau}, \gamma_{\max})$ we have $\gamma D(\bar{\tau},\gamma) < \gamma D(\underline{\tau},\gamma) < v\sqrt{B}$ for all $\gamma \leq \gamma_{\max}$, implying that both $\bar{\lambda}(\gamma; B)$ and $\underline{\lambda}(\gamma; B)$ are decreasing in γ over $[0, \gamma_{\max}]$; they are obviously increasing in B. Inverting these functions with respect to γ yields the claimed properties of $\underline{\gamma}(\lambda; B)$ and $\bar{\gamma}(\lambda; B)$. ■

Proof of Proposition 8. Consider a firm $\hat{\imath} \in [0,1]$ with technology $\hat{\sigma}$ and associated productivity factor $\hat{A} \equiv A(\hat{\sigma})$. Its marginal cost is:

$$MC(\hat{\sigma}|\sigma_t) \equiv \min_{\{\hat{x}_t^i\}} \left\{ \int_0^1 p_t^i\, \hat{x}_t^i\, di \;\middle|\; \hat{A} \cdot \left(\int_0^1 z_t^i\; \left(\hat{x}_t^i\right)^{\frac{\hat{\sigma}-1}{\hat{\sigma}}}\; d\,s \right)^{\frac{\hat{\sigma}}{\hat{\sigma}-1}} = 1 \right\}. \tag{A.7}$$

The first-order condition for cost-minimization is:

$$
\begin{aligned}
p_t^i &= \hat{\mu}_t\ \hat{A}\ z_t^i\ \left(\hat{x}_t^i\right)^{\frac{-1}{\hat{\sigma}}} \cdot \left(\int_0^1 z_t^i\ \left(\hat{x}_t^i\right)^{\frac{\hat{\sigma}-1}{\hat{\sigma}}}\ d\,s\right)^{\frac{1}{\hat{\sigma}-1}} = \hat{\mu}_t\ \hat{A}\ z_t^i\ \left(\hat{x}_t^i\right)^{\frac{-1}{\hat{\sigma}}} \cdot \left(\hat{A}\right)^{-\frac{1}{\hat{\sigma}}}, \quad \text{or:} \\
\hat{x}_t^i &= \hat{\mu}_t^{\hat{\sigma}}\ \hat{A}^{\hat{\sigma}-1} \left(\frac{p_t^i}{z_t^i}\right)^{-\hat{\sigma}}.
\end{aligned}
$$

Therefore:

$$
\begin{aligned}
\hat{\mu}_t &= \int_0^1 p_t^i\, \hat{x}_t^i\, di = \hat{\mu}_t^{\hat{\sigma}}\ \hat{A}^{\hat{\sigma}-1} \left(\int_0^1 z_t^i\ \left(p_t^i/z_t^i\right)^{1-\hat{\sigma}}\ di\right), \quad \text{or:} \\
\hat{\mu}_t &= \hat{A}^{-1} \left(\int_0^1 \left(z_t^i\right)^{\hat{\sigma}}\ \left(p_t^i\right)^{1-\hat{\sigma}}\ di\right)^{\frac{1}{1-\hat{\sigma}}}, \qquad \text{(A.8)}
\end{aligned}
$$

which establishes (32). Now, replacing the equilibrium prices from equation (27) yields:

$$
\hat{\mu}_t = \hat{A}^{-1} A_t^{\frac{\sigma_t-1}{\sigma_t}} \left(\frac{y_t}{l_t}\right)^{\frac{1}{\sigma_t}} \left(\int_0^1 z_t^i\ \left(k_t^i\right)^{\frac{\hat{\sigma}-1}{\sigma_t}}\ di\right)^{\frac{1}{1-\hat{\sigma}}} = \hat{A}^{-1} A_t^{\frac{\sigma_t-1}{\sigma_t}} \left(\frac{y_t}{l_t}\right)^{\frac{1}{\sigma_t}} \left(\int_0^1 \left(k_t^i\right)^{\frac{\hat{\sigma}-1}{\sigma_t}}\ di\right)^{\frac{1}{1-\hat{\sigma}}},
$$

since the z_t^i's and k_t^i's are independent. We now eliminate the terms common to all firms by computing firm $\hat{\imath}$'s relative marginal cost:

$$
mc(\hat{\sigma}|\sigma_t) \equiv \frac{\hat{\mu}_t}{\mu_t} = \left(\frac{A_t}{\hat{A}}\right) \cdot \left(\int_0^1 \left(k_t^i\right)^{\frac{\hat{\sigma}-1}{\sigma_t}}\ di\right)^{\frac{1}{1-\hat{\sigma}}} \cdot \left(\int_0^1 \left(k_t^i\right)^{\frac{\sigma_t-1}{\sigma_t}}\ di\right)^{\frac{-1}{1-\sigma_t}}.
$$

Finally, using the fact that $\ln \int_0^1 (k_t^i)^{\chi}\, di = \exp\left[\chi m_t + \chi^2 \Delta_t^2/2\right]$ for all χ, this yields:

$$
mc(\hat{\sigma}|\sigma_t) = \left(\frac{A(\sigma_t)}{A(\hat{\sigma})}\right) \exp\left[\frac{\Delta_t^2}{2}\left(\frac{1-\hat{\sigma}}{\sigma_t^2} - \frac{1-\sigma_t}{\sigma_t^2}\right)\frac{\Delta_t^2}{2}\right] = \left(\frac{A(\sigma_t)}{A(\hat{\sigma})}\right) \exp\left[\frac{\Delta_t^2}{2}\left(\frac{\sigma_t-\hat{\sigma}}{\sigma_t^2}\right)\right]. \qquad \text{(A.9)}
$$

The (necessary and sufficient) first-order condition for firm $\hat{\imath}$ is therefore: $c'(\hat{\sigma}) = \Delta_t^2/2\sigma_t^2$. Evaluating it at $\hat{\sigma} = \sigma_t$ yields the technology-equilibrium condition $\sigma_t^2 c'(\sigma_t) = \Delta_t^2/2$, which by convexity of $c(\cdot)$ has a unique solution $\sigma^*(\Delta_t)$, increasing in Δ_t. Finally, the result that $\partial \ln \sigma^*/\partial \ln \Delta \in (0,1)$ is established in equation (35). ■

Proof of Section III.C's claims concerning growth with endogenous technology. In the general growth formula (12), $\delta \ln l_t$ is now replaced everywhere (according to (28)) by

$$
\ln \tilde{A}_t + \delta_t \ln l_t = \ln l_t + \ln\left(A_t^{\frac{\sigma_t-1}{\sigma_t}}\left(y_t\right)^{\frac{1}{\sigma_t}}\right) = \delta_t \ln l_t + \gamma_t \ln A(\sigma_t) + (1-\gamma_t)\ln y_t.
$$

This leads to:

$$\begin{aligned}\gamma_t \ln(y_{t+1}/y_t) &= \gamma_t \left[\ln \kappa + \beta \ln s + \delta_{t+1} \ln l_{t+1} - \alpha\delta_t \ln l_t + \ln A(\sigma_{t+1}) - \alpha \ln A(\sigma_t)\right] \\ &\quad -\gamma_t(1-\gamma_t)w^2/2 - \beta\gamma_t(1-\beta\gamma_t)(1-\tau_t)^2 v^2/2 \\ &\quad - \left[\alpha + \beta\gamma_t(1-\tau_t)^2 - (\alpha + \beta\gamma_t(1-\tau_t))^2\right]\gamma_t^2\Delta_t^2/2. \qquad \text{(A.10)}\end{aligned}$$

For $\alpha = 0$ and $\beta = 1$, this simplifies to:

$$\begin{aligned}\gamma_t \ln(y_{t+1}/y_t) &= \gamma_t \left[\ln \kappa + \ln s + \delta_{t+1} \ln l_{t+1} + \ln A(\sigma_{t+1})\right] \\ &\quad -\gamma_t(1-\gamma_t)\left[w^2/2 + (1-\tau_t)^2 v^2/2 + (1-\tau_t)^2\gamma_t^2\Delta_t^2/2\right] \\ &= \gamma_t \left[\ln \kappa + \ln s + \ln l_{t+1} + \ln A(\sigma_{t+1})\right] \\ &\quad -\gamma_t(1-\gamma_t)\left[w^2/2 + (1-\tau_t)^2 v^2/2 + (1-\tau_t)^2\gamma_t^2\Delta_t^2/2\right], \qquad \text{(A.11)}\end{aligned}$$

or, finally, since $\Delta_{t+1}^2 = \gamma^2(1-\tau_t)^2\,\Delta_t^2 + (1-\tau_t)^2\,v^2 + w^2$:

$$\begin{aligned}\ln(y_{t+1}/y_t) &= \ln \kappa + \ln s + \delta_{t+1} \ln l_{t+1} + \ln A(\sigma_{t+1}) - (1-\gamma_t)\Delta_{t+1}^2/2 \\ &= \ln \kappa + \ln s + \ln l_{t+1} - c(\sigma_{t+1}) - \frac{\Delta_{t+1}^2}{2\sigma_t}. \qquad \text{(A.12)}\end{aligned}$$

Substituting for Δ_{t+1}^2 from (11), the growth rate between t and $t+1$ is thus:

$$g_t = \ln \kappa + \ln s + \delta_{t+1} \ln l(\tau_{t+1}) - c(\sigma_{t+1}) - \frac{\mathcal{D}(\Delta_t, \tau_t; \gamma_t)^2}{2\sigma_t}.$$

Therefore, with fixed labor supply ($1/\eta = 0$), if all firms are forced to use technology $\sigma_t - d\sigma$ instead of σ_t in every period the impact on growth will be $d\sigma$ times

$$\begin{aligned}\left.\frac{\partial g_t}{\partial \sigma}\right|_{\sigma=\sigma_t} &= -c'(\sigma_{t+1}) + \frac{\Delta_{t+1}^2}{2\sigma_t^2} - \frac{\Gamma'(\sigma_t)}{2\sigma_t} \cdot \frac{\partial \mathcal{D}^2(\Delta_t, \tau_t; \gamma_t)}{\partial \gamma} \\ &= -\frac{\Delta_{t+1}^2}{2}\left(\frac{\sigma_t^2}{\sigma_t^2} - 1\right) - \frac{\Gamma'(\sigma_t)}{2\sigma_t} \cdot \frac{\partial \mathcal{D}^2(\Delta_t, \tau_t; \gamma_t)}{\partial \gamma},\end{aligned}$$

where we have used the condition for equilibrium technology choice in Proposition (8). The growth impact is thus positive in all periods provided that either $\sigma_{t+1}^2 \approx \sigma_t^2$ (we start in or near the steady state), or $\sigma_{t+1}^2 \leq \sigma_t^2$ (we start with "excessive" heterogeneity with respect to the steady state). ■

Proof of Proposition 10. We begin with some preliminaries. Given a technology σ and associated $\gamma = (\sigma - 1)/\sigma$, recall from (22)-(23) that the tax rate $\bar{\tau}$ is a steady-state political equilibrium, which we shall denote as $\bar{\tau} \in \mathcal{P}(\sigma; \lambda)$, if and only if $\lambda \leq \bar{\lambda}(\gamma, B)$. Similarly, $\underline{\tau} \in \mathcal{P}(\sigma; \lambda)$ if and only if $\lambda \geq \underline{\lambda}(\gamma, B)$.

Conversely, given a tax rate τ we see from (43) that the technology σ_L and associated $\gamma_L = (\sigma_L - 1)/\sigma_L$ is a technological steady state when the slope of the technology frontier is M, which we denote as $\sigma_L \in T(\tau; M)$, if and only if:

$$M \geq \frac{D(\tau;\gamma_L)^2}{2\sigma_L^2} \equiv R(\tau, \sigma_L). \tag{A.13}$$

Conversely, the technology σ_H and associated $\gamma_H = (\sigma_H - 1)/\sigma_H$ is a technological steady state, which we denote as $\sigma_H \in T(\tau; M)$, if and only if:

$$M \leq \frac{D(\tau;\gamma_H)^2}{2\sigma_H^2} \equiv R(\tau, \sigma_H). \tag{A.14}$$

A policy-technology combination $(\tau, \sigma) \in \{\bar{\tau}, \underline{\tau}\} \times \{\sigma_L, \sigma_H\}$ is then a full steady-state if and only if $\tau \in P(\sigma; \lambda)$ and $\sigma \in T(\tau; M)$. Clearly, there are at most four stable steady-states (we restrict attention here to cases where the technology equilibrium is in pure strategies). We now proceed through a sequence of three claims, which together establish the proposition.

Claim 1: for a country facing the technological frontier M, the only steady states are $(\bar{\tau}, \sigma_L)$ and $(\underline{\tau}, \sigma_L)$. Indeed, the first inequality in (45) states that $\sigma_L \in T(\underline{\tau}; M)$ and this is easily seen to imply that $\sigma_L \in T(\bar{\tau}; M)$. Conversely, the second inequality states that $\sigma_H \notin T(\underline{\tau}; M)$ and this is easily seen to imply that $\sigma_L \in T(\bar{\tau}; M)$. Finally, the fact that $\underline{\lambda}(\gamma_L; B) < \lambda < \bar{\lambda}(\gamma_L; B)$ due to (45) means that $\underline{\tau} \in P(\sigma_L; \lambda)$ and $\bar{\tau} \in P(\sigma_L'; \lambda)$.

Claim 2: for a country facing the technological frontier M', the only steady states are $(\bar{\tau}, \sigma_L)$ and $(\underline{\tau}, \sigma_H)$. Indeed, note first from (47) that $R(\bar{\tau}, \sigma_L) < M'$ means that we still have $\sigma_L \in T(\bar{\tau}; M')$; by contrast, $M' < \min\{R(\underline{\tau}, \sigma_L), R(\underline{\tau}, \sigma_H)\}$ means that $\sigma_H \in T(\underline{\tau}; M)$ but $\sigma_L \notin T(\bar{\tau}; M)$. The only possible equilibria are thus $(\bar{\tau}, \sigma_L)$, $(\underline{\tau}, \sigma_H)$ and $(\underline{\tau}, \sigma_H)$. Turning now to (45), the fact that $\lambda < \bar{\lambda}(\gamma_L; B)$ means that $\bar{\tau} \in P(\sigma_L'; \lambda)$; the fact that that $\bar{\lambda}(\gamma_H; B) < \lambda$, on the other hand, means that $\underline{\tau} \in P(\sigma_H; \lambda)$ but $\underline{\tau} \notin P(\sigma_H; \lambda)$. So only the first two of the three preceding configurations are full equilibria.

Claim 3: *for a country facing the technological frontier m, the only steady state is $(\underline{\tau}, \sigma_H)$.* Observe from (47) that m satisfies all the same inequalities as M', except that $m < R(\bar{\tau}, \sigma_L)$ whereas $R(\bar{\tau}, \sigma_L) < M'$. This means that whereas we had $\sigma_L \in T(\bar{\tau}; M')$, we now have $\sigma_L \notin T(\bar{\tau}; M')$. This rules out the equilibrium $(\bar{\tau}, \sigma_L)$, leaving only $(\underline{\tau}, \sigma_H)$. ■

Proof of Proposition 11.

Claim 1: in the initial parameter configuration, $(\bar{\tau}\ , \sigma_L)$ is a steady state (and even the only steady-state with policy $\bar{\tau}$). Indeed, the fact that $\bar{\lambda}(\gamma_H; B) < \lambda < \bar{\lambda}(\gamma_L; B)$ means that $\bar{\tau} \in \mathcal{P}(\sigma_L; \lambda)$, whereas $\bar{\tau} \notin \mathcal{P}(\sigma_H; \lambda)$. The rest of the claim follows from the fact $\sigma_L \in \mathcal{T}(\bar{\tau}; M)$, since $M > R(\bar{\tau}, \sigma_L)$.

Claim 2: After the political shift in C_1, $(\underline{\tau}, \sigma_H)$ is the only steady-state for that country. First, since $\lambda' > \bar{\lambda}(\gamma_L; B) > \bar{\lambda}(\gamma_H; B)$ we now have $\bar{\tau} \notin \mathcal{P}(\sigma_L; \lambda')$ and $\bar{\tau} \notin \mathcal{P}(\sigma_H; \lambda')$, so there is no steady-state with policy $\bar{\tau}$. Moreover, since $M < R(\underline{\tau}, \sigma_L)$ we have $\sigma_L \notin \mathcal{T}(\underline{\tau}; M)$, so the only possible equilibrium is $(\underline{\tau}, \sigma_H)$. It is indeed an equilibrium, as $M < R(\underline{\tau}, \sigma_H)$ means that $\sigma_H \in \mathcal{T}(\underline{\tau}; M)$, while $\bar{\lambda}(\gamma_H; B) < \lambda'$ means that $\underline{\tau} \in \mathcal{P}(\sigma_H; \lambda')$.

Claim 3: After C_1 has switched to the technology σ_H, so that C_2 faces the technology frontier m, the only steady-state for C_2 is $(\underline{\tau}, \sigma_H)$. First the fact $m < R(\bar{\tau}, \sigma_L) < R(\underline{\tau}, \sigma_L)$ implies that $(\bar{\tau}, \sigma_L)$ is no longer a technological equilibrium, and a fortiori neither is $(\underline{\tau}, \sigma_L)$. Second, the fact $m < \min\{R(\underline{\tau}, \sigma_L), R(\underline{\tau}, \sigma_H)\}$ means that the only technological equilibrium under policy $\underline{\tau}$ is σ_H. Finally, since $\lambda > \bar{\lambda}(\gamma_H; B)$, $\underline{\tau} \in \mathcal{P}(\sigma_H; \lambda)$ whereas $\bar{\tau} \notin \mathcal{P}(\sigma_H; \lambda)$, which concludes the proof. ■

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