mates are joint normally distributed in large samples, we get

$$E(\hat{b}_K^i \mid \hat{b}_K^j) = \frac{\text{cov}(\hat{b}_K^i, \hat{b}_K^j)}{\text{Var}(\hat{b}_K^j)} \hat{b}_K^j$$

$$= \rho_{ij}^2 \hat{b}_K^j,$$

where ρ_{ij} is the correlation between the stock returns in the countries i and j.

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THE JOURNAL OF FINANCE • VOL. XLVI, NO. 4 • SEPTEMBER 1991

Stock Markets, Growth, and Tax Policy

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ABSTRACT

An extensive literature documents the role of financial markets in economic development. To help explain this relationship, this paper constructs an endogenous growth model in which a stock market emerges to allocate risk and explores how the stock market alters investment incentives in ways that change steady state growth rates. The paper demonstrates that stock markets accelerate growth by (1) facilitating the ability to trade ownership of firms without disrupting the productive processes occurring within firms and (2) allowing agents to diversify portfolios. Tax policy affects growth directly by altering investment incentives and indirectly by changing the incentives underlying financial contracts.

AN EXTENSIVE LITERATURE DOCUMENTS and discusses the role of financial markets in economic development.[1] In an exhaustive study of three dozen developed and developing countries over the period 1860-1963, Goldsmith (1969) provides evidence of a positive relationship between the ratio of financial institutions' assets to GNP and output per person. Goldsmith also presents data showing "that periods of more rapid economic growth have been accompanied, though not without exception, by an above-average rate of financial development" (p. 48). In addition, Romer (1989) and others have shown, using cross-country data sets that range from 20 to over 100 years, that there exist startling differences in per capita output growth rates with no tendency for these growth rates to converge unconditionally.[2] This paper helps explain these observations which have not been previously reconciled within the context of a general equilibrium optimizing model.

Along with recent work by Bencivenga and Smith (1991), Greenwald and Stigliz (1989), and Greenwood and Jovanovic (1990), this paper constructs a model that links the financial system with the steady state growth rate of per capita output.[3] Specifically, the model extends and links two literatures. The

*Financial Policy and Systems Division, The World Bank. The views expressed in this paper are solely the responsibility of the author and should not be attributed to The World Bank, its Board of Directors, its management, or any of its member countries. I would like to thank Maria Carkovic, John Coleman, Dale Henderson, Eric Leeper, Giovanna Mossetti, Sergio Rebelo, an anonymous referee, and especially David Gordon for very helpful comments.

[1]See Cameron (1967), Goldsmith (1969), and McKinnon (1973).

[2]See Abramovitz (1986), DeLong (1988), Lucas (1988), and Levine and Renelt (1990).

[3]Bencivenga and Smith (1991) construct a bank that by pooling the economy's resources eliminates liquidity risk and invests more efficiently. Their equilibrium, however, suffers from Jacklin's (1987) incentive incompatibility problem, and since they do not formally distinguish between physical and human capital, it appears as if financial markets are trading ownership of human capital. In Greenwood and Jovanovic (1990), growth increases participation in a financial

endogenous growth literature, associated with the work of Romer (1986, 1990) and Lucas (1988), constructs models in which agents make decisions that fully determine the economy's steady state growth rate. The financial structures literature, associated with the work of Townsend (1979), Diamond and Dybvig (1983), and Diamond (1984), constructs models in which financial contracts emerge as optimal responses to an economy's informational and risk characteristics. This paper constructs an endogenous growth model in which a stock market emerges to allocate risk and explores how the stock market alters investment incentives in ways that change steady state growth rates.

As in most of the endogenous growth literature, steady state per capita growth only occurs in this paper if agents make investment decisions that yield sufficiently high rates of human capital accumulation and technological progress.[4] Human capital and technology are augmented in "firms," where groups of people invent, innovate, and produce together in a long-run process as in Prescott and Boyd (1987). Unique to this paper, there is an externality associated with physical capital in the creation of human capital; the average amount of capital maintained in a firm during the entire production process positively affects the human capital of each member independently of that individual's own investment. This externality implies that people who prematurely remove capital from firms reduce the rate of human capital accumulation of remaining members. Since growth is inextricably tied to human capital accumulation, premature capital liquidation retards economic growth.

This model has two characteristics that elicit the creation of financial contracts: liquidity risk and productivity risk. Productivity risk arises because firms are subject to productivity shocks in the final period of production. This productivity risk discourages risk averse investors from investing in firms. Stock markets allow individuals to invest in a large number of firms and diversify away idiosyncratic productivity shocks. Thus, stock markets can raise the fraction of resources devoted to human capital-augmenting firms and, thereby, accelerate per capita growth.

A second feature of the model that encourages financial contracting is liquidity risk, which is created by the model's Diamond and Dybvig (1983) preference structure. Specifically, agents choose how much to invest in firms that take a long time to produce and how much to invest in a less profitable but liquid asset that pays off quickly. The liquid asset does not augment

intermediary that provides information on the economy's aggregate shock. The improved information enhances investment choices and growth. In Greenwald and Stiglitz (1989), market imperfections arising from asymmetric information reduce investment and productivity growth.

[4]The literature typically uses the terms "technology" and "human capital" interchangeably. Romer (1990), however distinguishes technology—the instructions for combining raw materials into goods—from human capital—the ability to follow instructions and create new instructions. I assume that legal or technical considerations imply that newly invented technologies are only useful to the firms that create those new technologies. Thus, using Romer's (1990) terminology, firm-created technology is perfectly excludable and therefore economically indistinguishable from rival goods such as human capital.

human capital or technology and, therefore, does not contribute to growth. After making decisions, some individuals receive privately observed liquidity shocks and discover that they want to consume their wealth before the firms in which they have invested create new technologies, sell goods, and distribute profits. Even though the premature liquidation value of firm capital is small, agents receiving these privately observed shocks remove their capital from firms. Thus, the risk of receiving a liquidity shock and a very low premature liquidation return may discourage firm investment. If liquidity shocks were publicly verifiable, standard insurance contracts would eliminate the liquidity risk faced by individuals. Since liquidity shocks are not publicly observable, alternative financial contracts may arise to mitigate liquidity risk.

Stock markets may emerge in this model to help agents cope with liquidity risk by allowing those entrepreneurs receiving liquidity shocks to sell their "shares" to other investors. Agents who do not receive a liquidity shock will want to purchase shares with liquid assets because firms enjoy a higher expected rate of return than liquid assets. Thus, individuals do not verify whether other individuals have received liquidity shocks; agents simply trade in an impersonal, competitive stock market based on their own private information. One result is that capital is not prematurely removed from firms to satisfy short-run liquidity needs. Due to the externality in human capital production, remaining firm members enjoy a higher rate of human capital accumulation than they would in the absence of stock markets, and output grows faster. Furthermore, even without the externality, stock markets may encourage firm investment and growth by reducing the liquidity risk associated with firm investment.

If liquidity shocks were publicly observable, standard insurance contracts would produce the ex ante optimal sharing of output. Diamond and Dybvig (1983) argue that banks can structure the return on demand deposits so that individuals choose to withdraw deposits in a manner that reproduces the optimal sharing equilibrium without requiring that liquidity shocks be publicly observable. Jacklin (1987), however, demonstrates that the Diamond and Dybvig (1983) banking solution is feasible only if agents are restricted to investing *only* in banks; if a stock market opens, each investor would prefer to buy equity in the underlying technologies rather than invest in the bank.

This paper does not impose trading restrictions. Consequently, a competitive stock market arises to allocate risk. The resulting stock market equilibrium does not reproduce the optimal risk sharing equilibrium that exists with observable liquidity shocks or with banks that have a monopoly on savings. Nevertheless, the stock market equilibrium reduces risk and improves welfare above that of the nonfinancial-market case.[5]

The paper goes on to examine the implications of consumption, income, corporate, and capital gains taxes. I find that taxes associated with stock

[5]Within the Diamond and Dybvig (1983) model, Levine (1990) evaluates and ranks by the level of expected utility the equilibrium allocation of resources produced under various financial structures, e.g., stock markets, banks, mutual funds, and various trading restrictions.

market transactions reduce the fraction of resources devoted to firms and may also increase the fraction of firm capital removed prematurely. Both of these effects slow the rate of human capital accumulation and retard per capita output growth. Thus, given different policies toward financial markets, this paper explains cross-country and intertemporal differences in growth rates, the inability of measured factor inputs to explain these differences, and the close association between the relative size of the financial market and economic growth.

The next section describes the basic endogenous growth model without stock market trading. Section II examines the implications of stock market trading for risk sharing, resource allocation, and growth. Section III studies the effects of tax policy on long-run growth, and Section IV concludes.

I. The Basic Endogenous Growth Model

This section presents an endogenous growth model without financial markets. The model uses the Diamond and Dybvig (1983) structure of preferences to create liquidity risk and also includes productivity shocks that create production risk. Later sections study the effects of stock markets and policy.

A. Preferences and Technologies

The economy consists of an infinite sequence of three period lived agents, and a countable infinity of agents are born each period. There is no population growth. Young agents are identical with utility functions

$$u(c_1, c_2, c_3) = -\frac{[c_2 + \phi c_3]^{-\gamma}}{\gamma}, \tag{1}$$

where $\gamma > 0$, $\gamma + 1$ is the coefficient of relative risk aversion, and c_i is age i consumption. Since there is no utility from age one consumption, all income is saved. Thus, the financial system and policy cannot alter the savings rate.

The agent-specific, privately observed random variable ϕ becomes known at the start of the second period of life, and is distributed as

$$\phi = \begin{cases} 0 & \text{with probability } 1 - \pi, \\ 1 & \text{with probability } \pi. \end{cases} \tag{2}$$

The preference structure implies a "desire for liquidity" because agents want to consume their wealth at age two if $\phi = 0$. Since each agent's "type" (ϕ) is unknown at age one, there is "liquidity risk." But, there is no aggregate liquidity risk: $(1 - \pi)$ of each generation are type 0 and π are type 1. Since types are not publicly observable, insurance contracts tied to the observation of each agent's type cannot eliminate private liquidity risk.

Young agents are endowed with one unit of labor that is inelastically supplied to firms. Agents born in period t work, receive wage w_t, and make investment allocation decisions.

There are two production opportunities. The first is a liquid "storage" technology. Investment of one good at t yields $n > 0$ goods at $t + 1$ or $t + 2$. The second production technology involves the risky and illiquid activity of forming and investing in "firms" that have a higher expected return than the liquid technology. In a two-stage, two-period process, consumption goods are produced using capital, labor, and human capital. Human capital is nontradable and represents the knowledge and skills embodied in individuals.

In the first stage of firm production, individuals augment human capital. This takes period $t + 1$ and some of period $t + 2$, so that only age three agents have human capital. Each individual's accumulation of human capital depends positively on (1) his interactions with others (see Lucas (1988)), (2) the amount of resources invested by the individual, and (3) the average amount of capital invested and maintained in the firm for two periods. Letting q equal the fraction of age one income w_t invested in the firm by an agent born in t, his human capital h is

$$h_{t+2} = H\overline{W}_{t+2}^{\delta}(qw_t)^{\varepsilon}, \qquad 1 < \delta, \varepsilon < 0, \tag{3}$$

where H is a constant, qw_t is the resources invested by the agent, and $\overline{W}_{t+2}$ is the average quantity of resources maintained in the firm between t and $t + 2$; $\overline{W}_{t+2} = (1 - \bar{\alpha}^t)(\overline{qw}_t)/\pi$, where $\bar{\alpha}^t$ is the average fraction of resources removed from firms at $t + 1$, $\overline{qw}_t$ is the average quantity of resources per entrepreneur invested at t, and π is the fraction of initial members remaining at $t + 2$. The externality associated with physical capital in the creation of human capital may arise for a number of reasons. First, there may be a public-good externality associated with firm resources. Second, a member who benefits from his own investment will influence the human capital of others via group interactions. Finally, resources invested by one member may allow him to interact more with others, so that the human capital of other members rises independently of their own investments.

In the second stage of firm production, age three firm members with human capital—"entrepreneurs"—hire age one workers and produce goods (y):

$$y_{t+2} = \tilde{\eta}_{t+2} h_{t+2} L_{t+2}^{1-\theta}, \qquad 0 < \theta < 1, \tag{4}$$

where L_{t+2} is age one labor units hired per entrepreneur in $t + 2$ and $\tilde{\eta}_t$ is a firm specific productivity shock with an expected value of one.[6] The level of

[6]Formally, for each firm indexed by j, $\tilde{\eta}_t^j$ is drawn from the distribution function $G[\eta_t^j]$ on a compact interval $[\underline{\eta}, \bar{\eta}]$, where $\underline{\eta} > 1 - \theta$, and where $E[\eta] = \int \eta \, dG(\eta) = 1$.

human capital per entrepreneur at $t+2$ is h_{t+2}.[7,8] Firm investment is illiquid. An investor who prematurely liquidates firm capital at $t+1$ receives a very low return of x goods per investment, where $0 < x < n$.

The labor market is competitive, and labor is supplied inelastically. Age one labor is paid a wage rate equal to its expected marginal product,

$$w_{t+2} = (1-\theta)h_{t+2}L_{t+2}^{-\theta}. \tag{5}$$

Therefore, the return to each age three entrepreneur in firm j is

$$r_{t+2}^{j} = \left[\tilde{\eta}_{t+2}^{j} + \theta - 1\right]h_{t+2}L_{t+2}^{1-\theta} = \left[\tilde{\eta}_{t+2}^{j} + \theta - 1\right]H\overline{W}_{t+2}^{\delta}L_{t+2}^{1-\theta}(qw_t) \tag{6}$$

Human capital h positively influences production, the wage rate, and the return to entrepreneurs.

B. Non-Stock Market Economy: Trading, Equilibrium, and Growth

Agents born at t work during t, receive wage w_t, and choose to invest the proportion q in firm j, placing the remaining resources in the safe, liquid asset. At age two, type 0 agents consume their stored goods $[(1-q)w_t n]$ plus the premature liquidation value of their firm investment $[xqw_t]$. They regret having invested in firms. Since all type 0 agents remove their firm resources at $t+1$, the average amount of capital maintained in firms for two periods, $\overline{W}_{t+2}$, is lower than if no resources were removed prematurely.

At age two, type 1 agents do not liquidate firm capital. In fact, type 1 agents wish they had invested more in the firm because the expected return is higher than the liquid asset. At age three, type 1 agents complete the human capital accumulation stage of firm production. They hire age one labor, produce goods given a productivity shock, pay labor, and distribute profits based on initial investments. Thus, type 1 agents consume their stored goods $[(1-q)w_t n]$ plus the profits from the firm in which they invested r_{t+2}^{j}.

Thus, a representative agent born at t solves the problem

$$\max_{q} E_{\tilde{\eta}}\left(-\frac{\left(1-\pi\right)\left[qw_t x + (1-q)w_t n\right\}\right]^{-\gamma}}{\gamma} - \frac{\pi\left[\left(\tilde{\eta}_{t+2}^{j} + \theta - 1\right)H\overline{W}_{t+2}^{\delta}(qw_t)^{\varepsilon}L_{t+2}^{1-\theta} + (1-q)w_t n\right]^{-\gamma}}{\gamma}\right) \tag{7}$$

[7]To focus on the role of technology and human capital in development, this paper abstracts from physical factor accumulation in consumption goods production. Nevertheless, capital is pivotal in human capital creation, and the model can be easily extended to include capital resources in the production of consumption goods without altering the results; e.g., think of h as a composite human/physical capital good. Interestingly, Maddison (1987) finds that changes in measurable factor inputs such as capital and labor are able to account for considerably less than half of the observed growth rates in per capita output over the past 100 years.

[8]In terms of the standard neoclassical growth model, h_{t+2} is "technology." In contrast to the standard growth model, technology in this model is the result of the decisions of maximizing agents.

where $E_{\tilde{\eta}}$ is the expected value operator with respect to the distribution on $\tilde{\eta}$. Since only π of a generation become entrepreneurs and L_t is age one labor per entrepreneur, $L_t = 1/\pi$. Also, in this economy, all type 0 agents prematurely remove firm capital so that $\bar{\alpha}^{i} = 1-\pi$. Thus, in equilibrium,

$$L_t^{1-\theta} = \pi^{\theta-1} = \psi, \quad \text{and} \quad \overline{W}_{t+2} = (1-\bar{\alpha}^{i})(\overline{qw})/\pi = w_t q. \tag{8}$$

The first order condition after substituting (8) and assuming $\varepsilon + \delta = 1$ is[9]

$$\frac{(1-\pi)[x-n]}{\left[xq + n(1-q)\right]^{1+\gamma}} + \pi E_{\tilde{\eta}}\left(\frac{(\tilde{\eta}+\theta-1)\varepsilon H\psi - n}{\left[(\tilde{\eta}+\theta-1)H\psi q + n(1-q)\right]^{1+\gamma}}\right) = 0. \tag{9}$$

The first term in (9) is the increment to utility if q is marginally increased given that the agent is type 0; the second term is the expected increment to utility if q is marginally increased given that the agent is type 1. There is a solution to equation (9) where $0 \le q \le 1$ if $\pi\varepsilon\theta H\psi > n > x > 0$ and x can be set close to zero. This condition merely requires that the expected return from firm investment is greater than the return to liquid assets which in turn is greater than the premature liquidation value of firm capital.[10]

Assume that $\pi\varepsilon\theta H\psi > n > x > 0$ and decompose the expected value term in (9) to obtain

$$\frac{(1-\pi)[x-n]}{\left[xq + n(1-q)\right]^{1+\gamma}} + \pi\frac{[\varepsilon\theta H\psi - n]}{\left[\theta H\psi q + n(1-q)\right]^{1+\gamma}} + \pi\,\mathrm{Cov}\left([(\tilde{\eta}+\theta-1)\varepsilon H\psi - n], \frac{1}{\left[(\tilde{\eta}+\theta-1)H\psi q + n(1-q)\right]^{1+\gamma}}\right) = 0. \tag{10}$$

The covariance term is—contingent on the agent being type 1—the covariance between the expected return to marginally increasing firm investment and the marginal utility of consumption. This covariance is always negative.

To examine the factors determining the portfolio decision q, first assume that the productivity shock has zero variance ($\tilde{\eta}^{j} = 1$ for all j), which implies that the covariance term in equation (10) is zero, and solve for q.

$$q = \frac{n(\lambda-1)}{(R-n) + \lambda(n-x)},$$

[9]Steady state per capita growth can occur as long as $\varepsilon + \delta \ge 1$. Making this an equality allows one to solve for a closed form solution.

[10]If the return from liquid assets is higher than the expected return from firms, then there would be no firm investment. If, on the other hand, the liquidation value of firm capital is higher than the return from liquid assets, then no agent invests in liquid assets. Thus, if $\pi\varepsilon\theta H\psi > n > x$ does not hold, a relatively uninteresting corner solution results.

where

$$\lambda = \left[\frac{\pi(\varepsilon R - n)}{(1-\pi)(n-x)}\right]^{\frac{1}{1+\gamma}} \quad \text{and} \quad R = H\theta\psi. \tag{11}$$

The fraction of resources allocated to firms depends positively on the share of output going to entrepreneurs, θ, the rate of human capital accumulation, H, labor per entrepreneur, ψ, the liquidation value of firm investment, x, the probability of being type 1, π, and the fraction of marginal returns internalized by individuals, ε.[11] Finally, there is less firm investment the greater is the degree of relative risk aversion γ.

Now let the variance of the productivity shock be greater than zero, so that the covariance term in equation (10) is negative, not zero. Note that the summation of the first two terms in (10) varies inversely with q. Therefore, if the variance of $\tilde{\eta}$ increases, the absolute value of the covariance term increases, so that q must fall to satisfy condition (10). The economic implication of this finding is intuitively appealing: the variance of the productivity shock discourages risk-averse investors from investing in firms. Consequently, a market that allows investors to diversify risk will induce individuals to invest more in firms.

The two-period equilibrium growth rate of this economy is

$$g_y = y_{t+2}/y_t = h_{t+2}/h_t = \frac{H\overline{W}_{t+2}^{\delta}(qw_t)^{\varepsilon}}{h_t}.$$

Substituting equilibrium values and letting $\rho = (1-\theta)\pi^{\theta}$,

$$g_y = H\left[(1-\theta)\pi^{\theta}\right]q = H\rho q = H\rho\left[\frac{n(\lambda-1)}{(R-n)+\lambda(n-x)}\right]. \tag{12}$$

Per capita growth is inextricably linked to human capital accumulation: the faster the rate of human capital accumulation, the faster the growth rate of per capita output. In general, g_y may be greater or less than one, so that growth may be positive or negative.

Three points are worth noting here. First, since the aggregate savings rate is trivially set to one, only the *form* of savings, q, and the efficiency with which resources are employed, $\overline{W}$, can alter growth. Second, since $1-\pi$ of the population are type 0, they prematurely remove their capital from firms. This lowers firm efficiency by reducing the rate of human capital accumulation of remaining firm members which slows economic growth. Thus, an institution or market that helps minimize the liquidation of capital will increase firm efficiency and may also encourage firm investment. Finally, productivity risk retards economic growth by reducing the fraction of resources allocated to firms. A financial arrangement that allows agents to diversify against productivity shocks will raise q and accelerate growth.

[11] The term ε arises because agents do not fully internalize the effects of investing in firms [see equation (3)]. This model incorporates the notion that individuals perceive diminishing marginal returns to firm investment. If individuals see themselves instead as buying a share of final firm output proportional to their own investments, then the return to firm investment is $H\theta\psi\overline{W}_{t+2}(qw/\overline{qw})$. The results under this specification can be obtained from this paper by setting ε to 1.

II. Stock Markets and Growth

Liquidity risk and productivity risk create incentives for the formation of stock markets. Productivity risk lowers welfare and discourages agents from investing in firms. Stock markets allow investors to invest in a large number of firms and diversify away idiosyncratic productivity shocks. This raises welfare, the fraction of resources invested in firms, and the economy's steady state growth rate. In addition, liquidity risk also tends to lower welfare and firm investment. At the beginning of period two, the liquidity shock is revealed. Those who value period three consumption (type 1 agents) want to buy more shares while those receiving liquidity shocks (type 0 agents) want to consume their wealth at age two. In the previous section, there was no mechanism by which heterogeneous agents could trade, so that type 0 agents prematurely withdrew capital from firms to the detriment of remaining firm members. With a "stock market", however, agents can conduct mutually and socially beneficial transactions. In principle, ownership trading in response to liquidity shocks could occur strictly within firms even when types are not publicly observable. Public stock markets, however, provide a standardized mechanism for satisfying liquidity requirements, and stock markets allow individuals to hold diversified portfolios.

Stock markets affect growth in two ways. The first involves firm efficiency and depends on the externality in human capital production. Stock markets increase firm efficiency by eliminating the premature withdrawal of capital from firms. This accelerates the growth rate of human capital and per capita output. The second way stock markets can affect growth is to raise the fraction of resources devoted to firms. This does not necessarily depend on externalities. By increasing the liquidity of firm investment, reducing productivity risk, and improving firm efficiency, stock markets encourage firm investment. This stimulates human capital production and growth.

A. Stock Market Equilibrium

Stock market transactions occur in the first part of each period. Age one agents form firms and sell shares—claims on $t+2$ profits. Agents invest in a large number of firms to diversify against productivity shocks. At the beginning of $t+1$, agents learn their types. The resulting heterogeneity creates an incentive for stock transactions. Agents who do not value age three consumption will sell shares as long as they receive a price at least equal to the liquidation value of firm capital, x. Agents who value period three consumption will purchase more shares as long as the price in terms of stored goods is less than one.

Letting P equal the period two stock market price of claims to period three goods, a rational expectations equilibrium involves: (i) finding agents' optimal consumption/investment decisions in period two, given P and period one investment decisions, (ii) finding a P that clears the market in period two,

given period one investment decisions, (iii) finding the optimal period one investment decision, given P, and (iv) requiring period one market clearing.

Using "s" to distinguish the stock market economy from the financially autarkic economy, a preliminary result will help characterize the equilibrium.

Proposition 1: *In an economy with a stock market, if* $\varepsilon\pi R^s > n > x$, *then*

(i) *no firm resources are prematurely liquidated, and*
(ii) *all stored goods are consumed by type 0 agents.*

Proof: See Appendix I. Note $R^s = \theta\psi H\pi^{-\delta}$.

The condition for Proposition 1 to hold, $\varepsilon\pi R^s > n > x$, has already been assumed, and the implications for violating the condition are discussed in footnote (10).

Given Proposition 1, type 0 agents consume their stored goods $[(1 - q^s)nw_t]$ plus the stock market value of their claims to period $t + 2$ firm produced goods, i.e,. the value of their firm stock $[P\pi\theta\psi H(\overline{W}^s_{t+2})^{\delta}(q^s w_t)^{\varepsilon}]$. Type 1 agents consume their initial share of firm output $[\pi\theta\psi H(\overline{W}^s_{t+2})^{\delta}(q^s w_t)^{\varepsilon}]$ plus the additional share of firm output that they purchase on the stock market with stored goods $\left[\dfrac{(1 - q^s)nw_t}{P}\right]$ in $t + 1$.

Assuming that agents hold diversified portfolios, agents solve

$$\max_{q^s} -\left(\frac{1-\pi}{\gamma}\right)\left[(1 - q^s)nw_t + P\pi\theta\psi H\left(\overline{W}^s_{t+2}\right)^{\delta}\left(q^s w_t\right)^{\varepsilon}\right]^{-\gamma} - \left(\frac{\pi}{\gamma}\right)\left[\pi\theta\psi H\left(\overline{W}^s_{t+2}\right)^{\delta}\left(q^s w_t\right)^{\varepsilon} + \frac{(1 - q^s)nw_t}{P}\right]^{-\gamma}. \tag{13}$$

As Proposition 1 establishes, no firm capital is liquidated; thus, $(1 - \bar{\alpha}^i) = 1$, so that $\overline{W}^s_{t+2} = w_t\bar{q}^s/\pi$.

Solving (13) and using these equilibrium conditions yields

$$\varepsilon\pi R^s P = n. \tag{14}$$

Now, conjecture that $P = \dfrac{(1 - \bar{q}^s)n}{(1 - \pi)R^s\bar{q}^s}$, substitute into (14), and solve for q^s,[12]

$$q^s = \frac{\varepsilon\pi}{1 - \pi + \varepsilon\pi}. \tag{15}$$

[12]This P and q^s represent a rational expectations equilibrium. Appendix I finds optimal period two decisions, given P and q^s, and shows the set of P values that clear the period two market. Given q^s, $P = n/\varepsilon\pi R^s$, which is consistent with period two optimization and market clearing as described in Appendix I. The investment decision, q^s, is optimal from the solution to (13), and q^s obviously clears the market in period one. Also, note that with a stock market, agents voluntarily relinquish their ability to liquidate firm investment; there is a vertical supply curve of shares [see Appendix I].

The period one investment decision does not depend on risk aversion because individuals face a fixed, linear price for claims on period three goods. A change in q by any individual does not affect stock prices.[13]

In comparing the investment decision in an economy with a stock market, equation (15), with that of a non-stock market economy, equation (11), there are parameter values such that without a stock market there is no investment in firms, but the mere addition of stock markets changes incentives sufficiently so that individuals invest in firms. Since firm investment permits human capital creation and growth, financial policies that prohibit the formation of capital markets may severely discourage technological progress and economic development.

B. *The Growth Rate with a Stock Market*

The (two period) equilibrium growth rate is

$$g^s_y = H\pi^{-\delta}\rho q^s = H\pi^{-\delta}\rho\,\frac{\varepsilon\pi}{1 - \pi + \varepsilon\pi}. \tag{16}$$

In comparing the growth rate of the stock market economy with that of the non-stock market economy, there are two channels through which stock markets influence growth. First, stock markets increase firm efficiency. Even if the investment decisions q and q^s are equal, the stock market economy will grow faster than the non-stock market economy because stock markets eliminate the premature liquidation of firm capital. Instead of liquidating capital, agents that receive liquidity shocks sell their shares to agents that value period three consumption. Consequently, more capital is maintained in firms for two periods, which accelerates the rate of human capital accumulation. Formally, the externality associated with capital in the production of human capital $\overline{W}$ rises from qw in the non-stock market economy to qw/π in the stock market economy.

The second way in which stock markets influence growth is by increasing the fraction of resources allocated to firms. As equations (13) and (16) demonstrate, the higher the proportion of the economy's resources invested in firms, the faster will be the steady state growth rate. If agents are sufficiently risk averse, the proportion of resources devoted to firms is higher with a stock market ($q^s > q$). By allowing agents to diversify productivity risk, stock markets encourage risk-averse agents to invest more in firms. In addition, stock markets reduce the liquidity risk associated with firm investment; agents that receive liquidity shocks can sell their shares for more than the liquidation value of firm capital. Finally, by increasing firm efficiency, stock markets raise the return on firm investment. Thus, the emergence of stock markets to manage productivity and liquidity risk accelerates growth by attracting resources to socially productive firms.

[13]Banks, however, that pool and invest the savings of individuals recognize that alterations in q change stock prices. See Levine (1990).

Since the savings rate is fixed at one in this model, stock markets may only promote growth by increasing the productivity of firms or improving the allocation of resources. This coincides with the World Bank's (1989) finding of a positive relationship between the efficiency of investment – the change in GNP divided by investment – and the relative size of the financial system but little relationship between financial markets and savings rates.

III. Tax Policy, The Stock Market, and Growth

The source of growth in this model is human capital creation. Since the rate of human capital accumulation is positively related to the quantity of resources invested and maintained in firms, public policies that lower investment in firms, ceteris paribus, lower per capita growth rates. Therefore, either a reduction in the fraction of an economy's resources devoted to human capital augmenting firms or a reduction in the total quantity of resources available for investment will lower the economy's growth rate.

This section formally verifies this intuition by examining the implications of four marginal taxes: a consumption tax τ^c, a tax on wage earnings τ^w, a corporate or firm tax τ^f, and a capital gains tax τ^g, which taxes stock market transactions at rate τ^g.[14] The taxes alter equations (1), (5), and (6). Using logarithmic preferences to simplify derivations, we have

$$u(c_1, c_2, c_3) = \ln\left[(1-\tau^c)c_2 + \phi(1-g\tau^c)c_3 + T\right], \tag{1'}$$

where T is government transfers,

$$w_{t+2} = (1-\tau^f)(1-\tau^w)(1-\theta)\pi^\theta h_{t+2},^{15} \text{ and} \tag{5'}$$

$$r^j_{t+2} = (1-\tau^f)\left[\tilde{\eta}^j_{t+2} + \theta - 1\right] h_{t+2} L^{1-\theta}_{t+2}. \tag{6'}$$

Individuals have no influence over government transfers, and the government does not invest.

Given the revised structure, Proposition 1 becomes:

Proposition 2: *if* $(1-\tau^g)(1-\tau^f)\varepsilon\pi R^s > n > x$, *then*

(i) *no firm resources are prematurely liquidated, and*
(ii) *all stored goods are consumed by type 0 agents.*

Proof: Straightforward, given the proof to Proposition 1 in Appendix I.

Intuitively, the proposition indicates that as long as the tax system does not alter the model's structure no firm capital is prematurely liquidated and all liquid assets are "paid" to agents that do not value period three consumption in exchange for their claims to period three goods.

[14]See Levine and Renelt (1990) for a cross-country empirical study of policy and long-run growth.

[15]Equation (5') is obtained by an entrepreneur choosing L_t to maximize $(1-\tau^f)h_t L_t^{1-\theta} - w_t^b L_t$, where w_t^b is the wage rate before labor pays taxes.

Assuming that agents hold diversified portfolios, agents solve

$$\max_q -\left(\frac{1-\pi}{\gamma}\right)\ln\left[(1-\tau^c)(1-q)nw_t + (1-\tau^c)(1-\tau^g)(1-\tau^f)P\pi\theta\psi H\bar{W}^\delta_{t+2}(qw_t)^\gamma\right] - \left(\frac{\pi}{\gamma}\right)\ln\left[(1-\tau^c)(1-\tau^f)\pi\theta\psi H\bar{W}^\delta_{t+2}(qw_t)^\gamma + \frac{(1-\tau^c)(1-q)nw_t}{P}\right]. \tag{17}$$

The first order condition after substituting the equilibrium conditions is

$$\frac{(1-\pi)\left[(1-\tau^g)(1-\tau^f)P\varepsilon\pi R^s - n\right]}{\left[(1-q)n + (1-\tau^g)(1-\tau^f)P\pi R^s q\right]} = \frac{\pi\left[n - (1-\tau^f)P\varepsilon\pi R^s\right]}{\left[(1-q)n + (1-\tau^f)P\pi R^s q\right]}. \tag{18}$$

The first policy result is immediate. Since the consumption tax does not appear in the first order condition, it does not affect investment decisions or the economy's growth rate. This occurs because the consumption tax affects all elements of utility equally. If leisure were valued but not taxed, or partially taxed, then a rise in the consumption tax would induce a substitution into leisure and a reduction in growth.

Now, conjecture that $P = \dfrac{(1-\bar{q}^s)n}{(1-\tau^f)(1-\pi)R^s\bar{q}^s}$ and solve for q.[16]

$$q^{s\tau} = \frac{\{\pi/(1-\pi)\}\varepsilon\pi[1-\pi+(1-\tau^g)\pi] + (1-\tau^g)\varepsilon\pi}{\{\pi/(1-\pi)\}[1-\pi+\varepsilon\pi][1-\pi+(1-\tau^g)\pi] + [1-\pi+(1-\tau^g)]\varepsilon\pi}. \tag{19}$$

where the superscript "$s\tau$" signifies the stock market economy with taxes.

The per capita growth rate is

$$g_y^{s\tau} = h_{t+2}/h_t = (1-\tau^f)(1-\tau^w)H\pi^{-\delta}\rho q^{s\tau}. \tag{20}$$

Equation (20) indicates that wage and corporate taxes lower growth by reducing the quantity of resources available for future production. Since wages equal savings, a wage tax is a direct tax on investable resources. Since all wages are saved, this model exaggerates the effect of a wage tax on growth. Similarly, the corporate tax shifts back the demand curve for labor and reduces the equilibrium wage rate, lowering investment. If the corporate tax is large enough, firm investment and growth will stop.

Capital gains taxes, or in this model taxes on stock market transactions, also affect per capita growth rates. The capital gains tax may be broadly interpreted as official regulations and impediments to financial market transactions as well as direct taxation of stock market activities. These "taxes" do not directly lower the quantity of investable resources. Rather, capital gains taxes alter resource allocation by reducing the expected aftertax

[16]Appendix II derives equation (21). Furthermore, it is trivial to verify that this is a rational expectations equilibrium given the definition in Section II.

resale value of firm stock. This reduces the fraction of resources invested in firms and the economy's steady state growth rate.[17] Thus, cross-country differences in financial market policies may help explain the observed differences in per capita growth rates. If the impediments to capital market transactions are large enough to cause financial dis-intermediation, the economy returns to the slower growth equilibrium of financial autarky in which some firm capital is prematurely liquidated.

The relative size of the financial system as a fraction of gross domestic product is a commonly used measure of the significance of the financial system. In the current model, this may be approximated by taking the ratio of stock market transactions of generation t (transactions in $t + 1$) to the output generated by generation t (production in $t + 2$). For example, with an economy with only a corporate tax, this ratio is $(1 - \pi)\pi(1 - \pi^f)\theta$. Since the growth rate of this economy is $g_y^{s\tau} = (1 - \tau^f)H\pi^{-\delta}\rho q^{s\tau}$ and $q^{s\tau}$ is independent of τ^f, the relative size of the financial system will be positively correlated with the economy's growth rate.

The model has many avenues through which public policy can positively influence welfare. For example, the government could perform the revenue neutral policy of raising consumption taxes and reducing corporate taxes. This would reduce distortions, increase the allocation of resources to firms, and speed the economy's growth rate. One could also study the growth effects of specific types of public expenditures as in Barro (1990).

In this model, one can ask: which marginal tax reduction induces the greatest improvement in growth? Appendix II shows that the wage and corporate taxes are more potent than the capital gains tax when evaluated at small marginal tax rates. Since the corporate and wage taxes are taxes on savings, their effects are probably exaggerated. Therefore, this result should not be taken too seriously but should instead stimulate further inquiry into the relationship between policy, financial markets, and growth.

IV. Conclusion

This paper addressed the question: how does trading of financial assets and tax policy affect economic growth? The paper examines a model in which liquidity and productivity risk elicit the creation of a stock market and studies how the resulting stock market changes the incentives of investors in ways that alter steady state growth rates. In particular, stock markets accelerate growth by (1) facilitating the ability to trade ownership of firms without disrupting the productive processes occurring within firms and (2) allowing investors to hold diversified portfolios. Tax policy in this model influences growth directly by altering investment incentives and indirectly by affecting the functioning of financial markets in ways that alter investment incentives. Thus, within the context of a simple model, this paper helps explain the documented relationship between financial development, long-run growth, and policy. Unfortunately, there is no channel in this model through which economic growth can stimulate changes in financial markets.

In the model, growth only occurs if society invests and maintains a sufficient amount of capital in firms that augment human capital and technology in the process of production. The more resources allocated to firms, the more rapid will be economic growth. An externality in firm production implies that the economy grows faster when investors do not prematurely liquidate firm capital to satisfy short-run liquidity needs. Thus, financial arrangements that encourage firm investment or eliminate the premature removal of firm capital accelerate the steady state growth rate of per capita output.

Stock markets arise in this model to help agents manage liquidity and productivity risk, and, in so doing, stock markets accelerate growth. In the absence of financial markets, firm-specific productivity shocks may discourage risk-averse investors from investing in firms. Stock markets, however, allow individuals to invest in a large number of firms and diversify against idiosyncratic firm shocks. This raises the fraction of resources allocated to firms, expedites human capital accumulation, and promotes economic growth.

In the model without stock markets, liquidity shocks force some agents to remove capital from firms prematurely and receive a very low liquidation return. Thus, liquidity shocks not only discourage firm investment because of the risk of receiving a low liquidation return, liquidity shocks also reduce firm productivity because premature removal of firm capital retards the rate of technological innovation. Stock markets, however, allow those agents plagued by liquidity shocks to sell their stock to other investors for more than the low liquidation return, and no firm capital is prematurely removed from firms. Consequently, stock markets accelerate growth directly by eliminating premature capital liquidation which increases firm productivity and indirectly by reducing liquidity risk which encourages firm investment.

This paper shows that taxing or impeding financial market activity lowers per capita growth rates. If we take policies toward financial markets as given exogenously, policy can explain the three stylized facts discussed in my introduction; that is, different policies toward financial markets can lead to vastly different long-run per capita growth rates; they can lead to these differences without relying on variations in capital and labor; and these policy differences will induce the observed positive correlation between financial market activity and growth.

Appendix I

This appendix proves Proposition 1, derives $\overline{W}$ in the stock market economy, and demonstrates that individuals voluntarily relinquish the option of prematurely liquidating firm capital if a stock market exists.

At age two each agent has a claim to $\pi\theta\psi H\overline{W}_{t+2}^{\delta}(qw_t)^{\epsilon}$ units of period three good given period one decisions. He can turn these claims into xqw period two consumption goods. Recall that $\pi\theta\psi H\overline{W}_{t+2}^{\delta}(qw_t)^{\epsilon} > xqw$.

[17] Appendix II shows this formally.

The period two supply and demand curves for claims to period three goods demonstrate that a rational expectations equilibrium implies that no firm resources are prematurely removed. If $P > 1$, *all* agents sell claims on period three goods. At $P = 1$, type 1 agents are indifferent between selling or not selling claims to period three goods. Set $\underline{P} = x/[\pi\theta\psi H\overline{W}^{\delta}_{t+2}(qw_t)^{\epsilon-1}]$. At $\underline{P} < P < 1$, type 1 agents do not sell claims to period three goods while type 0 agents sell all their claims. If $P = \underline{P}$, type 0 agents are indifferent between liquidating firm investment and selling their claims to period three goods. And, for $P < \underline{P}$, type 0 agents liquidate their stake in the firm; there is no supply of claims to period three consumption goods. This gives rise to the period two stock market supply curve for period three consumption goods depicted in Figure 1 as *abcde*.

The demand curve for period three goods is given in Figure 1 as *ABCDEF*. At $P > 1$, no agent relinquishes period two goods for period three goods. At $P = 1$, type 1 agents are indifferent between consuming their stored goods in period two or purchasing period three goods. At $P < P < 1$, type 1 agents use stored goods to purchase period three goods. Thus, the area under the demand curve along *CD* is $\pi(1 - q)nw$, which is the stock of period two goods owned by type 1 agents. At $P = \underline{P}$, type 1 agents not only want to purchase period three goods with stored goods but are also indifferent between liquidating firm capital and purchasing period three goods via the stock market. Finally, at $P < \underline{P}$, type 1 agents want to use stored goods *and* the liquidation value of firm capital to purchase period three goods in the stock market.

A rational expectations equilibrium does not exist at $P \geq 1$ or $P \leq \underline{P}$. At $P \leq \underline{P}$, everyone liquidates investment in all firms. Also, $P \leq \underline{P}$ implies that all agents store more goods in period one.[18] If everyone stores more goods, the demand curve shifts out, and the supply curve shifts back so that the intersection occurs on the *CD* part of the demand curve and the *cd* part of the supply curve. This implies that no capital is liquidated ($\alpha^i = 0$), and $\overline{W}^{\delta} = \{\bar{q}w/\pi\}^{\delta}$. The relevant supply curve is vertical at $(1 - \pi)\pi R^s qw$; therefore, individuals voluntarily relinquish the option of liquidating firm capital.

If $P \geq 1$, everyone increases period one firm investment.[19] Such a P is not a rational expectations equilibrium. The altered investment decision causes the demand and supply curves to shift until an intersection occurs on *CD* and *cd*. Thus, all stored goods are consumed by type 0 agents.

Thus, if $\epsilon\pi\theta\psi H\pi^{-\delta} > n > x$, a rational expectations equilibrium can only occur on the *CD* part of the demand curve and on the *cd* part of the supply curve; all of the goods stored in period one are consumed by type 0 agents, and no physical investment in the firms is removed prematurely.

[18]Since $n > x$, those receiving $\phi = 0$ would have preferred to store more goods. Those receiving $\phi = 1$ would also have preferred to store more goods because then they would have more period two goods with which to purchase period three goods at P. Since all agents would increase the proportion of stored resources if they expect $P \leq \underline{P}$, such a P is not a rational expectations equilibrium.

[19]Consider, for example, $P = 1$. At this price, everyone simply maximizes claims on period two or period three goods. A marginal increase in the proportion of period one wealth allocated to the firm increases claims to period two or period three goods (at $P = 1$) by $\epsilon\pi\theta\psi H\overline{W}^{\delta}_{t+2}w_t q^{\epsilon-1}$, which in equilibrium equals $\epsilon\pi\theta\psi H\pi^{-\delta}w_t$, and lowers them by nw_t. It follows that if $\epsilon\pi\theta\psi H\pi^{-\delta} > n$, then at $P \geq 1$ all agents will increas the proportion of their period one wealth invested in the firm.

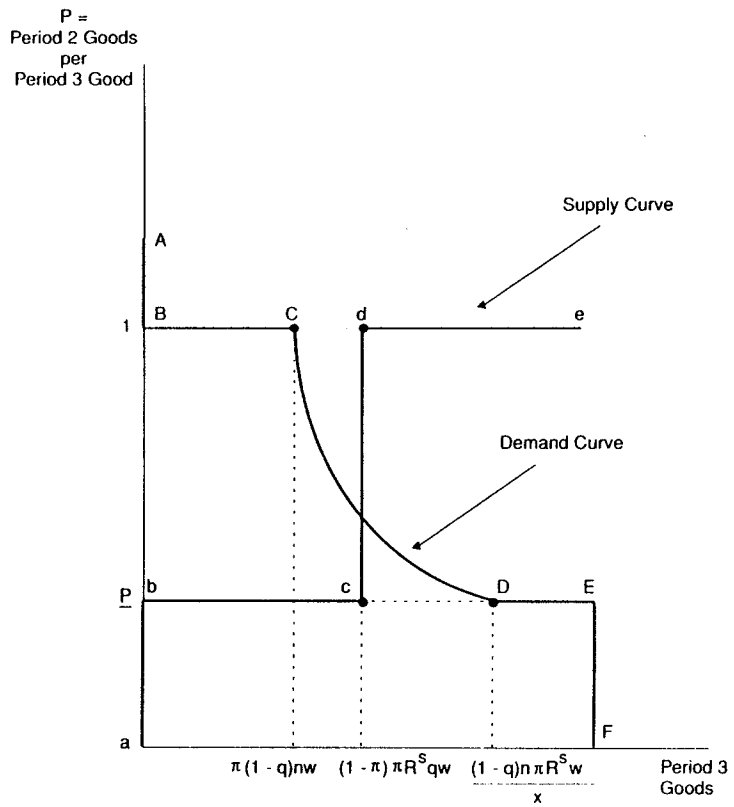

Figure 1. Stock market equilibrium. Stock market trading in period two represents trading of period two and period three goods. The equilibrium price lies between $\underline{P}$ and 1. The supply curve of period three goods is *abcde*. If $P > \underline{P}$, then agents that have received a liquidity shock will supply all of their claims to period three goods: $(1 - \pi)\pi R^s qw$. If $P > 1$, then all agents would supply period three goods. The demand curve for period three goods is *ABCDEF*. If $P < 1$, agents that have not received liquidity shocks will demand period three goods with their stored goods, so that the area under the demand curve along *CD* is $\pi(1 - q)nw$, which equals $\underline{P}(1 - q)n\pi R^s w/x$. If $P < \underline{P}$, then all agents would prematurely liquidate their firm investments.

Appendix II

This appendix (A) derives the investment decision in a stock market economy with taxes that satisfies the rational expectations equilibrium conditions, (B) derives the effect of a marginal change in the capital gains tax on investment and growth, and (C) demonstrates that a marginal reduction in the wage or corporate tax has a more positive impact on growth than a marginal reduction in the wage or corporate tax has a more positive impact on growth than a marginal reduction in the capital gains tax.

A. *Derivation of* $q^{s\tau}$

The maximization problem is given by equation (17) in the text:

$$\max_{q} -\left(\frac{1-\pi}{\gamma}\right)\ln\left[(1-\tau^c)(1-q)nw_t + (1-\tau^c)(1-\tau^g)(1-\tau^f)P\pi\theta\psi H\overline{W}^{\delta}_{t+2}(qw_t)^{\varepsilon}\right] - \left(\frac{\pi}{\gamma}\right)\ln\left[(1-\tau^c)(1-\tau^f)\pi\theta\psi H\overline{W}^{\delta}_{t+2}(qw_t)^{\varepsilon} + \frac{(1-\tau^c)(1-q)nw_t}{P}\right]. \quad (17)$$

The first order condition after substituting the equilibrium conditions is

$$\frac{(1-\pi)\left[(1-\tau^g)(1-\tau^f)P\varepsilon\pi R^s - n\right]}{\left[(1-q)n + (1-\tau^g)(1-\tau^f)P\pi R^s q\right]} = \frac{\pi\left[n - (1-\tau^f)P\varepsilon\pi R^s\right]}{\left[(1-q)n + (1-\tau^f)P\pi R^s q\right]}. \quad (18)$$

Conjecture that $P = \dfrac{(1-\bar{q}^s)n}{(1-\tau^f)(1-\tau)R^s\bar{q}^s}$, and solve for q. Substituting,

$$\frac{(1-\pi)\left[(1-\tau^g)\varepsilon\pi(1-q)/(1-\pi)q - 1\right]}{\left[(1-q) + (1-\tau^g)\pi(1-q)/1-\pi\right]} = \frac{\pi\left[1-\varepsilon\pi(1-q)/(1-\pi)q\right]}{\left[\pi(1-q)/(1-\pi) + (1-q)\right]}. \quad (B1)$$

Simplifying yields

$$\frac{(1-\pi)\left[(1-\tau^g)\varepsilon\pi(1-q) - (1-\pi)q\right]}{\left[1-\pi+(1-\tau^g)\pi\right]} = \pi\left[(1-\pi)q - \varepsilon\pi(1-q\right], \quad (B2)$$

and

$$\frac{q\left[1-\pi+(1-\tau^g)\varepsilon\pi\right] + (1-\tau^g)\varepsilon\pi}{q\left[1-\pi+\varepsilon\pi\right] - \varepsilon\pi} = \frac{\pi}{(1-\pi)}\left[1-\pi+(1-\tau^g)\pi\right]. \quad (B3)$$

Now, let:

$$a = 1-\pi+\varepsilon\pi, \qquad A = \varepsilon\pi,$$

$$b = 1-\pi+(1-\tau^{\kappa})\varepsilon\pi, \quad B = (1-\tau^{\kappa})\varepsilon\pi, \quad \text{and} \quad C = 1-\pi+(1-\tau^{\kappa})\pi,$$

so that

$$\frac{qb+B}{qa-A} = \frac{\pi C}{1-\pi}, \quad (B4)$$

where $a > b$, $A > B$, $a > A$, and $b > B$.
Finally, solving for q yields equation (19) in the text:

$$q = \frac{\dfrac{\pi}{1-\pi}AC + B}{\dfrac{\pi}{1-\pi}aC + b}. \quad (21)$$

B. *The Effects of the Capital Gains Tax*

Note that

$$\frac{\partial A}{\partial\tau^{\kappa}} = \frac{\partial a}{\partial\tau^{\kappa}} = 0, \qquad \frac{\partial B}{\partial\tau^{\kappa}} = \frac{\partial b}{\partial\tau^{\kappa}} = -A, \quad \text{and}$$
$$\frac{\partial C}{\partial\tau^{\kappa}} = -\pi\left[1-\pi+(1-\tau^{\kappa})\pi\right] < 0. \quad (B5)$$

Therefore,

$$\frac{\partial q^{s\tau}}{\partial\tau^g} = \frac{\left[\left(\dfrac{\pi}{1-\pi}\right)A\dfrac{\partial C}{\partial\tau^g} - A\right]\left[\left(\dfrac{\pi}{1-\pi}\right)aC + b\right]}{D} - \frac{\left[\left(\dfrac{\pi}{1-\pi}\right)a\dfrac{\partial C}{\partial\tau^g} - A\right]\left[\left(\dfrac{\pi}{1-\pi}\right)AC + B\right]}{D} \quad (B6)$$

where

$$D = \left[\left(\frac{\pi}{1-\pi}\right)aC + b\right]^2.$$

To sign this derivative consider the numerator of (B6) which equals

$$\left(\frac{\pi}{1-\pi}\right)\left(\frac{\partial C}{\partial\tau^g}\right)\left[Ab - aB\right] - \left(\frac{\pi}{1-\pi}\right)AC\left[a-A\right] - A\left[b-B\right]. \quad (B7)$$

Since $a > A$ and $b > B$, the last two terms of (B7) are negative. Recall that $\partial C/\partial \tau^g < 0$. If $Ab - aB > 0$, then the first term is negative and $\partial q/\partial \tau^g$ is negative.

$$\begin{aligned} Ab - aB &= \varepsilon\pi\left[(1 - \pi + (1 - \tau^g)\varepsilon\pi) - (1 - \tau^g)(1 - \pi + \varepsilon\pi)\right] \\ &= \varepsilon\pi\left[(1 - \pi) + (1 - \tau^g)\varepsilon\pi - (1 - \tau^g)(1 - \pi) - (1 - \tau^g)\varepsilon\pi\right] \\ &= \varepsilon\pi(1 - \pi)\tau^g > 0, \end{aligned}$$

so that $\partial q/\partial \tau^g < 0$, which necessarily implies that $\partial g^{s\tau}/\partial \tau^g < 0$.

C. Tax Rate Comparison

Now compare the growth effects of marginally altering the wage, corporate, and capital gains taxes at low marginal tax rates. In particular, evaluate

$$\left.\frac{\partial g^{s\tau}}{\partial \tau^g}\right|_{\tau^w=\tau^f=\tau^g=0}, \quad \left.\frac{\partial g^{s\tau}}{\partial \tau^f}\right|_{\tau^w=\tau^f=\tau^g=0}, \quad \left.\frac{\partial g^{s\tau}}{\partial \tau^w}\right|_{\tau^w=\tau^f=\tau^g=0}.$$

First note that

$$\left.\frac{\partial g^{s\tau}}{\partial \tau^f}\right|_{\tau^w=\tau^f=\tau^g=0} = \left.\frac{\partial g^{s\tau}}{\partial \tau^w}\right|_{\tau^w=\tau^f=\tau^g=0} = -H\pi^{-\delta}\rho q\big|_{\tau^w=\tau^f=\tau^g=0};$$

substituting for $q\,|_{\tau^w=\tau^f=\tau^g=0}$ yields

$$\left.\frac{\partial g^{s\tau}}{\partial \tau^f}\right|_{\tau^w=\tau^f=\tau^g=0} = \left.\frac{\partial g^{s\tau}}{\partial \tau^w}\right|_{\tau^w=\tau^f=\tau^g=0} = \frac{-H\pi^{-\delta}\rho\varepsilon\pi}{1 - \pi + \varepsilon\pi}. \tag{B8}$$

Now consider

$$\left.\frac{\partial g^{s\tau}}{\partial \tau^g}\right|_{\tau^w=\tau^f=\tau^g=0} = H\pi^{-\delta}\rho\left.\frac{\partial q^s}{\partial \tau^g}\right|_{\tau^w=\tau^f=\tau^g=0}.$$

Noting that

$$\left.\frac{\partial C}{\partial \tau^g}\right|_{\tau^w=\tau^f=\tau^g=0} = -\pi(1 + \gamma) \quad \text{and} \quad C\,|_{\tau^w=\tau^f=\tau^g=0} = 1,$$

it is easy to show that

$$\left.\frac{\partial g^{s\tau}}{\partial \tau^g}\right|_{\tau^w=\tau^f=\tau^g=0} = \frac{-H\pi^{-\delta}\rho\varepsilon\pi(1 - \pi)^2}{(1 - \pi + \varepsilon\pi)^2}. \tag{B9}$$

Now compare (B8) with (B9). Since $1 > (1 - \pi)^2/(1 - \pi + \varepsilon\pi)$,

$$Abs\left.\frac{\partial g^{s\tau}}{\partial \tau^w}\right|_{\tau^w=\tau^f=\tau^g=0} = Abs\left.\frac{\partial g^{s\tau}}{\partial \tau^f}\right|_{\tau^w=\tau^f=\tau^g=0} > Abs\left.\frac{\partial g^{s\tau}}{\partial \tau^g}\right|_{\tau^w=\tau^f=\tau^g=0}$$

so that a marginal decrease in the wage or corporate tax has a larger positive impact on growth than a marginal decrease in the capital gains tax.

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