HOW EFFECTIVE ARE PORTFOLIO MANDATES?*

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Abstract

We evaluate the impact of responsible investing mandates on real capital allocation. We show that the modeling framework—endowment vs. production economies—significantly influences the assessment of mandate effectiveness. The current literature, based on endowment-economy intuition, focuses on differences in the cost of capital as a measure of mandate effectiveness. We show that in production economies with close to constant return to scale, the cost of capital is a misleading measure of effectiveness: a mandate can significantly impact capital allocation without any effect on the cost of capital. In a dynamic stochastic general equilibrium model calibrated to match U.S. macroeconomic and asset pricing moments, at least 50% of the intended impact of the mandate is achieved in equilibrium, resulting in a 4% long-run increase in the share of capital in the sector favored by a mandate. Our analysis suggests that the recent debate on responsible investing, which heavily relies on endowment-economy models and finds small cost of capital differences, may lead to incorrect inferences about mandate effectiveness.

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I. Introduction

Responsible investing, a set of strategies whose goal is to generate social and environmental impact alongside financial returns, has experienced significant growth over the last decade.[1] Common implementations of these strategies take the form of portfolio mandates that aim to restrict capital allocation to particular firms, leading to an increase in their cost of capital. Krueger, Sautner, and Starks (2020) document how institutional investors have been changing their investment decisions to account for climate risk. Likewise, concerns over social responsibility have led to pressure on institutions to divest from companies with business ties to Israel and Russia.[2] Despite the phenomenal recent growth in responsible investing, the academic literature to date provides a skeptical view of its effectiveness. For example, Heinkel, Kraus, and Zechner (2001) and, more recently, Berk and van Binsbergen (2024) argue that responsible-investing policies are effective only if they increase the cost of capital of undesirable firms. Following this logic, a large and growing body of empirical work measures differences in the cost of capital as a way to infer the impact of responsible investing on capital allocation.[3]

In this paper, we argue that the cost of capital is generally not an accurate metric for assessing the effectiveness of portfolio mandates. Using both a static and a dynamic model we show that portfolio mandates can lead to substantial differences in sectoral capital allocation, even with negligible difference in the sectoral cost of capital. Our analysis extends beyond the context of socially responsible investing to other cases where portfolio constraints are imposed to influence investors' behavior, such as regulatory compliance and economic sanctions.[4]

[1]The Global Sustainable Investment Alliance (2022) report estimates that \$8.4tr out of \$66.6tr of professionally managed assets are subject to a sustainability mandate. PricewaterhouseCoopers (2022) forecasts that assets under management that are screened by Environmental, Social, and Governance (ESG) criteria are expected to increase from \$18.4tr in 2021 to \$33.9tr by 2026, with ESG assets on pace to constitute 21.5% of total global assets under management.

[2]On the other hand, partly on the grounds that it reduces investment returns, several states in the US have introduced proposals *against* responsible investing, see, e.g., Donefer (2023), Mayer (2023). Because this pushback, asset managers have started rethinking their ESG-investing stance, e.g., JP Morgan and State Street have left the Climate Action 100+ group, Vanguard supported none of the 400 ESG proposals it considered in the 2024 US proxy season, and BlackRock voted in favor of only 4 percent of such measures (Financial Times, August 29 2024).

[3]There is also a large practitioner literature that uses the change in the cost of capital to gauge the effectiveness of various socially responsible policies. See, for instance, the article from McKinsey "Why ESG is Here to Stay," that states, "…there have been more than 2,000 academic studies, and around 70 percent of them find a positive relationship between ESG scores on the one hand and financial returns on the other, whether measured by equity returns or profitability or valuation multiples." In contrast, Krueger, Alves, and van Dijk (2024) study the relation between ESG ratings and stock returns using 16,000+ stocks in 48 countries and seven different ESG rating providers and find little evidence that ESG ratings are related to stock returns.

[4]For example, Article 5 of Regulation (EU) No 833/2014, enacted after the onset of the war between Russia and Ukraine, states that "It shall be prohibited to directly or indirectly purchase, sell, provide investment services for or

The literature that uses the cost of capital as a measure of the effectiveness of responsible investment strategies typically draws its conclusions from the analysis of an "endowment" economy. In such an economy, a firm's dividend is exogenous, and its cost of capital is determined in equilibrium by the market clearing stock price. In contrast, in a production economy *both* dividends (payoffs or output) and asset returns are jointly determined endogenously in equilibrium. This difference has important implications for evaluating the effectiveness of portfolio mandates on capital allocation. We show, both conceptually and quantitatively, that, unlike in an endowment economy, portfolio mandates in a production economy can lead to significant differences in the equilibrium sectoral allocation of physical capital despite negligible differences in the cost of capital.

To understand the mechanism underlying this result, consider an economy with two sectors, "green", G, and "brown", B.[5] Firms in each sector use the capital K supplied by investors through their portfolio choice to produce output $Y = A\,K^{\alpha}$, with A a constant productivity parameter and $\alpha \in [0, 1]$ the returns-to-scale parameter. The case of $\alpha = 1$ represents the standard "AK" production economy with constant returns to scale. The case of $\alpha = 0$ represents an endowment economy in which output (dividend) is exogenously given, i.e., $Y = A$. The cost of capital for each firm is its marginal productivity of capital, that is, $R = \alpha A K^{\alpha-1}$. Therefore ratio between the cost of capital in the two sectors is then $R_G/R_B = (A_G/A_B) \times (K_G/K_B)^{\alpha-1}$.

In an endowment economy, $\alpha = 0$, which means that the cost of capital ratio is $R_G/R_B = (A_G/A_B) \times (K_G/K_B)^{-1}$. Therefore, a portfolio mandate that is effective in reducing the aggregate amount of capital allocated to B will lead to a corresponding increase in R_B relative to R_G. Thus, in the case of an endowment economy, differences in the cost of capital are a good proxy for mandate effectiveness.

In contrast, in a production economy with constant returns to scale, $\alpha = 1$, the cost of capital ratio is $R_G/R_B = A_G/A_B$, and hence it is independent of the distribution of aggregate capital across sectors. Thus, a portfolio mandate designed to increase K_G relative to K_B has *no effect* on the cost of capital. Because the returns in the two sectors are the same, unconstrained investors have no incentive to tilt their portfolio away from G toward B. Thus, in this case, the mandate can be fully effective in shifting capital to the G sector, even though it has no effect on the cost of capital.

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assistance in the issuance of, or otherwise deal with transferable securities" https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022R0328.

[5] Our analysis applies more generally to any economy in which mandates are imposed to favor capital allocation to a subset of sectors.

An alternate way to capture the same intuition is to interpret the return to scale parameter as a measure of scarcity of capital relative to entrepreneurial "ideas", represented by the production function $Y = AK^{\alpha}$.[6] When $\alpha = 1$, entrepreneurial ideas are abundant because it is possible to scale up any good idea ad infinitum. However, capital is scarce because only so much of it can be allocated to production. With decreasing return to scale ($0 < \alpha < 1$) capital becomes relatively more abundant than ideas because committing too much capital to any good idea reduces its productivity. In an endowment economy ($\alpha = 0$) capital is infinitely abundant relative to ideas, because no amount of extra capital can increase output, regardless of how productive an idea is. Much of the literature in corporate finance has focused on the case of scarce ideas and (infinitely) abundant capital, i.e., an endowment economy. This may be realistic in the short run or for small sectors of the economy. However, in our paper, we take the standard view in general equilibrium macroeconomics that the supply of capital must equal the demand for capital, with the cost of capital clearing this market.

The returns-to-scale/scarcity argument points out that the key to the mechanism we highlight is curvature. When there is little curvature with respect to capital in the production function, it is relatively easy to redeploy assets, and therefore, mandated assets are redeployed with little effect on assets not targeted by a portfolio mandate. In the intuition above and the simple static model we consider, the only sources of curvature are the returns to scale on the production side and risk aversion on the household side. However, the dynamic model we consider also contains realistically calibrated capital adjustment costs to study the transition dynamics resulting from the introduction of a mandate.[7]

We formalize these ideas by studying two versions of a production economy: (i) a single-period frictionless model with stochastic productivity shocks and risk-averse investors, and (ii) a dynamic stochastic general equilibrium model with realistic frictions calibrated to match macroeconomic and asset pricing moments in the US. The economy consists of two sectors (green and brown) and two groups of investors: one group is constrained by a portfolio mandate to either hold G assets or avoid B assets (e.g., pension funds), and the other group is unconstrained (e.g., hedge funds). Although, in reality, mandates may be imposed in response to externalities, e.g., pollution, we abstract away from modeling the rationale for their existence. We use the first model to develop

[6] We are grateful to Marcus Opp for suggesting this alternative interpretation.

[7] Besides curvature, the mandate's effectiveness would depend on the persistence of the green/brown characteristics of firms, the magnitude of depreciation, and the persistence and volatility of the productivity process. Our analysis is silent on these dimensions.

intuition and *qualitatively* evaluate the effectiveness of portfolio mandates in equilibrium. We use the second model to *quantitatively* assess the effectiveness of portfolio mandates and to study the transition dynamics following the imposition of mandates.

To measure the effectiveness of a portfolio mandate on the sectoral allocation of physical capital in equilibrium, we introduce the concept of *effective mandate pass-through ratio*. This ratio represents the fraction of the intended mandate impact that is actually achieved in equilibrium. To illustrate the main idea, consider an economy where both types of investors have equal wealth and both sectors have identical risk-return tradeoffs so that the optimal unconstrained allocation for both investors is to hold 50% of their portfolio in each sector. Suppose now that a mandate requires constrained investors to have 75% of their portfolio in the G sector. Ignoring the mandate's effect on equilibrium asset prices, the capital allocated to the G sector would be $(50\% + 75\%)/2 = 62.5\%$, which is 12.5% higher than in the absence of a mandate. We refer to this difference as the *intended* impact of the mandate. Because, in equilibrium, the mandate raises the demand for G capital, the price of the G asset increases relative to the B asset, which now becomes more attractive to unconstrained investors from a risk-return tradeoff. As a result, unconstrained investors may be willing to deviate from their original 50% portfolio by tilting their holdings toward B and away from G assets. This portfolio rebalancing of unconstrained investors undoes part of the mandate. If, after accounting for this rebalancing, the overall allocation of capital to G assets is, say, only 56.25%, then the *actual* mandate impact is only 6.25%. Therefore, the effective mandate pass-through ratio is $6.25\%/12.5\% = 50\%$; i.e., 50% of the mandate survives the equilibrium effects.

A natural way for a constrained investor to satisfy the mandate is to trade G for B shares with unconstrained investors in the secondary market. This trade would satisfy the constraint without altering the physical quantity of capital. As a result of this trade, however, unconstrained investors would hold an under-diversified portfolio and, therefore, demand a discount on the B shares. With constant returns to scale and in the absence of capital adjustment costs, the constrained investor could avoid this discount by simply being an "activist" and directly shifting physical capital from B to G assets in the primary market. This would allow the investor to meet the mandate while leaving the unconstrained investor perfectly diversified. In this case, the mandate would be fully effective. On the other hand, when there are decreasing returns to scale or capital adjustment costs, shifting physical capital is costly and, therefore, part of the mandate will be satisfied through trades in the secondary market. However, even in this case, the mandate will affect the real capital allocation in equilibrium.

To assess the quantitative effects of portfolio mandates, in our dynamic version of the production economy, we relax many of the simplifying assumptions made to develop the intuition in the single-period model. In particular, we consider an infinite-horizon, overlapping-generations economy (Blanchard, 1985) where investors have Epstein-Zin-Weill recursive preferences (Epstein and Zin, 1989, 1991), consume at each date, and are endowed with one unit of labor that they supply to firms inelastically. Firms are all-equity financed, incur convex capital-adjustment costs (e.g., Hayashi, 1982), and choose labor and investment to maximize shareholder value subject to a capital-accumulation constraint. For the case of constant returns to scale, $\alpha = 1$, and no portfolio mandates, our model is a canonical real-business-cycle model, similar to that in King, Plosser, and Rebelo (1988) and Jermann (1998), among many others. We calibrate the model to match asset pricing and macroeconomic moments in the US and use the solution to study the effect of portfolio mandates on the equilibrium cost of capital and capital allocation.

The solution of the multiperiod model confirms the central intuition highlighted in the one-period model. When a mandate is imposed, unconstrained investors face a trade-off: On the one hand, the desire to diversify pushes the portfolio toward a 50/50 allocation. On the other hand, the mandate makes the brown sector more attractive from a risk-reward perspective and induces unconstrained investors to tilt their portfolios toward it. In equilibrium, the optimal portfolio decisions of unconstrained investors "undo" some of the intended effects of the portfolio mandate. However, we find that, under a realistic calibration of the model, portfolio mandates retain a quantitatively significant impact in equilibrium. For example, under the calibration designed to capture representative moments of the "Current Green Economy," the effective mandate pass-through ratio is at least 50%. In contrast, the effect on the equilibrium cost of capital is negligible, consistent with evidence in the existing literature. To assess the robustness of these findings, we also solve several alternative versions of our baseline economy, including decreasing returns to scale, different mandate designs, and different sizes of the green and brown sectors. Overall, we find that the pass-through is stronger when investors are more risk averse, when the mass of constrained investors is larger, when the mandate is weaker but spread over a larger mass of investors, when returns to scale are high, and when investors' labor income is less correlated with investment income.

In summary, our analysis suggests that in a dynamic general equilibrium production economy designed to match the macroeconomic and asset pricing moments of the US economy, portfolio mandates can have a quantitatively significant impact on aggregate capital allocation in the primary market, even if their effect on the cost of capital is negligible. This result sharply contrasts with the conclusion one would draw from studying endowment economies, where, by construction, the only impact of a mandate is through asset repricing in secondary markets. Our analysis suggests that to properly assess the effectiveness of portfolio mandates, it is essential to measure the *quantity* of capital flowing to the mandated sectors instead of its effect on the *cost* of capital.

Literature. Our paper relates to the growing literature on socially responsible investing. This literature can be broadly classified along two main strands: exclusion ("exit") and engagement ("voice"). The first strand of this literature focuses on a "discount-rate channel" in that it studies the effects of limiting (or excluding entirely) investment in certain firms from an investor's portfolio on the cost of capital of targeted firms. The key mechanism in this literature is reduced risk-sharing, which affects the cost of capital in an endowment economy; see, e.g., Heinkel, Kraus, and Zechner (2001), Zerbib (2019, 2022), Pástor, Stambaugh, and Taylor (2021, 2022), Pedersen, Fitzgibbons, and Pomorski (2021), Broccardo, Hart, and Zingales (2022), Sauzet and Zerbib (2022), De Angelis, Tankov, and Zerbib (2023), Cheng, Jondeau, Mojon, and Vayanos (2024), and Berk and van Binsbergen (2024). Notably, Heinkel et al. (2001) and Berk and van Binsbergen (2024) focus on the result that the effect on risk premia is small if profit-seeking investors can substitute for the capital they are restricted from holding. This intuition implies that mandates are effective only if they lead to significantly higher costs of capital for brown firms. Unlike Heinkel et al. (2001) and Berk and van Binsbergen (2024), who focus solely on the impact of mandates in secondary financial markets, our work examines their effects in both primary and secondary markets.

Some empirical studies, e.g., Hong and Kacperczyk (2009) and Bolton and Kacperczyk (2021, 2023) find a higher cost of debt and equity financing for brown (or "sin") firms although the magnitudes are not substantial, especially for debt financing.[8] Other studies find insignificant or even lower returns for brown firms.[9] Eskildsen, Ibert, Jensen, and Pedersen (2024) replicate the literature's wide range of "equity greenium" estimates and show that these are not robust to changes in the greenness measure or time period. Our paper revisits this evidence by considering a production economy and studies the quantitative effects of portfolio mandates in a calibrated model designed to match key asset pricing and macroeconomic moments. We show that mandates can be effective even if they do not impact the cost of capital. Hartzmark and Shue (2022) provide another reason why the cost-of-capital channel may be ineffective in achieving a greener economy.

[8] See, e.g., El Ghoul, Guedhami, Kwok, and Mishra (2011), Goss and Roberts (2011), Chava (2014), Zerbib (2019), Fatica, Panzica, and Rancan (2021), Huynh and Xia (2021), Aswani and Rajgopal (2022), Baker, Bergstresser, Serafeim, and Wurgler (2022), Seltzer, Starks, and Zhu (2022), Pástor et al. (2022).

[9] See, e.g., Larcker and Watts (2020), Tang and Zhang (2020), Flammer (2021), and Kontz (2023).

They show empirically that a reduction in the cost of capital for green firms that are already green leads to only small further improvements.

The second strand of the literature on socially responsible investing focuses instead on the "cash-flow channel." Broccardo et al. (2022), following Hart and Zingales (2017), conclude that "voice" is more effective than "exit." Oehmke and Opp (2024) study how mandates influence firms' technology choices in a model with production externalities and financing frictions. They show that socially responsible funds effectively subsidize firms' adoption of clean technologies. In the terminology of Oehmke and Opp (2024), in our paper, we have a "narrow mandate" in the short run, where there is a change in ownership but no real change in capital across sectors, while we have an "impact mandate" in the long run, where there is a real reallocation of capital from the brown to the green sector. Our focus on production economies allows us to consider jointly the cash-flow and discount-rate channels emphasized separately by the engagement and exclusion literature, respectively.

A few recent papers have considered the role of mandates and investors' preferences for social responsibility in the context of a production economy. For example, Hong, Wang, and Yang (2023) introduce decarbonization capital in a representative-agent dynamic stochastic general-equilibrium model and investigate the effectiveness of sustainable finance mandates in mitigating externalities within the economy. Because the economy has a representative agent, the mandate in their economy is, by definition, effective. In contrast, we study an economy with heterogeneous agents, with only a fraction of investors subject to a mandate. Our finding that mandates can substantially impact equilibrium capital allocation aligns with their conclusion that mandates can effectively address externalities. Dangl, Halling, Yu, and Zechner (2023a,b) study how different types of investor preferences affect equilibrium capital allocation. They find that if investments are endogenous, the effect of social preferences on corporate decisions may be sizable even if the difference in the cost of capital between the green and brown sectors is negligible. Finally, Betermier, Calvet, and Jo (2023) develop an empirically tractable model to characterize the supply and demand of capital in financial markets to quantify the impact of firm and investor characteristics on the equilibrium amount and cost of capital. We differ from these papers in that we consider a standard macroeconomic general equilibrium framework with heterogeneous agents and focus explicitly on studying portfolio mandates and their effectiveness for capital allocation. We show that portfolio mandates can affect capital allocations across sectors despite small differences in the cost of capital. We also illustrate that the degree of the returns to scale of capital in the economy has a crucial impact on the ability of portfolio mandates to influence equilibrium capital allocation. Our quantitative exercise is similar in spirit to Binsbergen and Opp (2019), who examine the importance of cross-sectional asset pricing anomalies for the real economy. We rely on a standard general equilibrium macroeconomic model to understand the importance of portfolio mandates across sectors and over time.

The rest of the paper proceeds as follows. In Section II, we develop intuition in a simple one-period (two-date) general equilibrium model. In Section III, we assess the real impact of portfolio mandates in a multiperiod general-equilibrium model with heterogeneous investors that is calibrated to match asset pricing and macroeconomic moments in the US economy. Section IV concludes. The appendix contains the proof for the results of the single-period model studied in Section II. Section OA.I of the Online Appendix provides details of the numerical solution of the multiperiod model studied in Section III, and Section OA.II shows how our two-date model maps into the model of Berk and van Binsbergen (2024) for the case of $\alpha = 0$, thus showing that an endowment economy is the limit of a production economy when the returns-to-scale parameter goes to zero.

II. A Simple Equilibrium Model with Portfolio Mandates

In this section, we present a stylized single-period (two-date) model of a production economy to highlight the key economic forces that drive the effectiveness of portfolio mandates in equilibrium. In the next section, we relax many of the simplifying assumptions to quantitatively evaluate the effectiveness of mandates in a multi-period model.

II.A. Setup

The economy consists of a continuum of firms and investors. At the initial date, $t = 0$, investors supply capital to firms. At the terminal date, $t = 1$, they consume the dividends received from their investments.

Firms. We assume that there are two sectors in the economy, and we refer to them as G and B. Each sector consists of a large number of atomistic, identical, all-equity-financed firms producing perfectly substitutable consumption goods. For example, this could describe the case of (brown) coal versus (green) solar-generated electricity, with consumers indifferent to how the electricity is made.[10] There are no externalities. We assume that capital is the only input of production and that output Y_j in sector j is given by the production function[11]

$$\tilde{Y}_j = \tilde{A}_j K_j^{\alpha}, \quad j = G, B, \tag{1}$$

where $\alpha \in [0,1]$ is the returns-to-scale parameter, $\tilde{A}_j$ denotes a random productivity shock, and K_j is the aggregate capital invested in sector j. We assume that the productivity shocks $\tilde{A}_j$ are normally distributed random variables, that is, $\tilde{A}_j \sim \mathcal{N}(\mu_{A_j}, \sigma^2_{A_j})$, $j = G, B$, and denote by ρ the correlation between $\tilde{A}_G$ and $\tilde{A}_B$.

Firms choose investment K_j in order to maximize their net present value (NPV_j), given by

$$\text{NPV}_j = \max_{K_j} \mathbb{E}[\tilde{M}\tilde{Y}_j] - K_j = \max_{K_j} \mathbb{E}[\tilde{M}\tilde{A}_j K_j^{\alpha}] - K_j, \tag{2}$$

with $\tilde{M}$ denoting the stochastic discount factor (SDF) that firms take as given. Firm j's optimal choice of capital K_j must then satisfy

$$\mathbb{E}[\tilde{M} \underbrace{\alpha \tilde{A}_j K_j^{\alpha-1}}_{:=\tilde{R}_j}] = 1. \tag{3}$$

The Euler equation (3) implicitly defines the return on invested capital,

$$\tilde{R}_j := \alpha \tilde{A}_j K_j^{\alpha-1} = \alpha \frac{\tilde{Y}_j}{K_j}, \quad j = G, B. \tag{4}$$

Because capital is the only input of production and can be adjusted costlessly, Tobin's Q is always equal to 1 and the realized profit is[12]

$$\tilde{\Pi}_j = \tilde{A}_j K_j^{\alpha} - \tilde{R}_j K_j = (1-\alpha)\tilde{A}_j K_j^{\alpha}. \tag{5}$$

Constant returns to scale, $\alpha = 1$, implies zero profits. Profits are positive when return to scale are decreasing, $\alpha < 1$. From equation (4), we can infer that firms' *demand for capital* as a function of the cost of capital $\mathbb{E}[R_j]$ is

$$K_j^{\text{demand}} = \left(\frac{\alpha \mu_{A_j}}{\mathbb{E}[\tilde{R}_j]} \right)^{\frac{1}{1-\alpha}}. \tag{6}$$

[10] An alternative is to model sectors producing imperfectly substitutable goods. For example, (brown) travel versus (green) telecommunication. We leave this case for future research but conjecture that the flow of capital out of the brown sector increases the price of brown goods and increases profits. This makes portfolio mandates more costly and, therefore, reduces their effectiveness. Sauzet and Zerbib (2022) and Chen, Garlappi, and Lazrak (2024) study an endowment economy with multiple goods and preferences for green assets and goods.

[11] In Section III, we consider a more general production function with capital and labor as inputs.

[12] Section III generalizes the model to allow for convex adjustment costs.

From equation (6) it follows that for $\alpha \in (0,1)$, firm j's demand for capital is inversely related to the cost of capital $\mathbb{E}[\tilde{R}_j]$. From equation (4), when $\alpha \to 1$, $\mathbb{E}[R_j] = \mu_{A_j}$ for all K_j, and therefore the demand curve is flat, implying that the demand for capital is *infinitely elastic*. In contrast, when $\alpha \to 0$, $K_j \to 0$ for all $\mathbb{E}[R_j]$, and the demand curve is vertical (at $K_j = 0$), implying that the demand elasticity is zero.

Investors. There is a continuum of identical investors who live for one period (two dates). Investors have mean-variance preferences over terminal wealth with identical risk-aversion parameter γ_a. Each investor is endowed with one unit of capital (wealth) to be allocated to G and B firms.

A fraction x of investors, denoted by c, face a constraint that either requires a minimum investment in G firms ("mandate") or restricts the maximum investment in B firms ("screen"). We assume that the constrained agents invest their unit capital endowment in the G and B firms according to the weights $\overline{w}_G$ and $\overline{w}_B$, with $\overline{w}_G + \overline{w}_B = 1$ and $\overline{w}_G \gg \overline{w}_B$. The remaining fraction $1 - x$ of investors, denoted by u, are unconstrained and choose their allocation to G and B firms optimally. We denote by $w_{j,u}$, $j = G, B$, the portfolio weight of unconstrained investors in firm j. From the expression of firm's profit in equation (5), firm j's payout to investors is $\tilde{R}_j K_j$, with $\tilde{R}_j$ defined in equation (4). Capital that is not invested in the G and B firms earns the risk-free rate R_f. When unconstrained investors invest $w_{j,u}$ units of capital in firm j, they receive a portion of the total payout $\tilde{R}_j K_j$ that is proportional to their contribution relative to the total capital invested in the firm, K_j. Specifically, the terminal consumption for the unconstrained investors is

$$\tilde{c}_u = (1 - w_{G,u} - w_{B,u})R_f + w_{G,u}\tilde{R}_G + w_{B,u}\tilde{R}_B + \tilde{\pi}_{G,u} + \tilde{\pi}_{B,u}, \tag{7}$$

where $\tilde{\pi}_{j,u}$ is the part of firm j's profit accruing to unconstrained investors that is outside their control. Unconstrained investors choose their optimal portfolio $w_{j,u}, j = G, B$, by solving the following problem[13]

$$\max_{w_{G,u}, w_{B,u}} \mathbb{E}[\tilde{c}_u] - \frac{\gamma_a}{2} \operatorname{Var}[\tilde{c}_u], \tag{8}$$

whose solution is characterized in the proposition below.

[13] We also studied a two-date model in which investors have CARA utility with consumption at not just the terminal date but also the initial date. The results from that model, available upon request, are very similar to those from the simpler model with mean-variance preferences, so we present the simpler model.

Proposition 1. *Given the return on investment* $\tilde{R}_j = \alpha \tilde{A}_j K_j^{\alpha-1}$, $j = G, B$ *from equation* (4) *and the risk-free rate* R_f, *the optimal portfolio of unconstrained investors is*

$$w_u = \frac{\alpha}{\gamma_a} \Sigma_R^{-1} (\mathbb{E}[\tilde{R}] - R_f \mathbf{1}), \tag{9}$$

which can be written explicitly in terms of the production parameters as

$$w_{G,u} = \frac{1}{\gamma_a(1-\rho^2)} \left(\frac{\mu_{A_G} K_G^{\alpha-1} - R_f/\alpha}{\sigma_{A_G}^2 K_G^{2(\alpha-1)}} - \rho \frac{\mu_{A_B} K_B^{\alpha-1} - R_f/\alpha}{\sigma_{A_G}\sigma_{A_B} K_G^{\alpha-1} K_B^{\alpha-1}} \right), \tag{10}$$

$$w_{B,u} = \frac{1}{\gamma_a(1-\rho^2)} \left(\frac{\mu_{A_B} K_B^{\alpha-1} - R_f/\alpha}{\sigma_{A_B}^2 K_B^{2(\alpha-1)}} - \rho \frac{\mu_{A_G} K_G^{\alpha-1} - R_f/\alpha}{\sigma_{A_G}\sigma_{A_B} K_G^{\alpha-1} K_B^{\alpha-1}} \right), \tag{11}$$

where Σ_R *denotes the covariance matrix of returns, whose elements are given by* $\mathrm{Cov}(\tilde{R}_j, \tilde{R}_\ell) = \alpha^2 \rho \sigma_{A_j} \sigma_{A_\ell} K_j^{\alpha-1} K_\ell^{\alpha-1}$, *with* $j, \ell \in \{G, B\}$.

Proposition 1 represents the unconstrained investors' *supply* of capital to sector j, taking as given the return $\tilde{R}_j$ and the risk-free rate R_f. The aggregate supply of capital $j = G, B$ after one accounts for the mandate is

$$K_j^{\text{supply}} = \underbrace{x\,\overline{w}_j}_{\substack{\text{supply of} \\ \text{constrained investor}}} + \underbrace{(1-x) w_{j,u}}_{\substack{\text{supply of} \\ \text{unconstrained investors}}} . \tag{12}$$

Notice that when returns to scale are constant, $\alpha = 1$, equations (10)–(11) simplify to

$$w_{G,u} = \frac{1}{\gamma_a(1-\rho^2)} \left(\frac{\mu_{A_G} - R_f}{\sigma_{A_G}^2} - \rho \frac{\mu_{A_B} - R_f}{\sigma_{A_G}\sigma_{A_B}} \right) \tag{13}$$

$$w_{B,u} = \frac{1}{\gamma_a(1-\rho^2)} \left(\frac{\mu_{A_B} - R_f}{\sigma_{A_B}^2} - \rho \frac{\mu_{A_G} - R_f}{\sigma_{A_G}\sigma_{A_B}} \right). \tag{14}$$

Therefore, in the case of $\alpha = 1$, the unconstrained investors' portfolio is unaffected by the amount of capital K_j and depends only on the risk-return tradeoff for each technology. A mandate $\overline{w}_G$ with the goal of increasing the aggregate supply of capital K_G in the economy does not lead to portfolio rebalancing by the unconstrained investors because it does not affect the risk-return tradeoff. Because the unconstrained investors' portfolio weights $w_{j,u}$ do not change in response to a mandate, the mandate is most effective in influencing the capital supply in the economy when $\alpha = 1$. We use this intuition below to construct a measure of mandate effectiveness.

Equilibrium. Proposition 1 provides the optimal portfolio and consumption choices of atomistic investors, *given* the return on capital, $\tilde{R}_j = \alpha \tilde{A}_j K_j^{\alpha-1}$, and the risk-free rate, R_f. The equilibrium aggregate capital *demanded* in sector j, K_j, and the risk-free rate R_f are determined by imposing the equilibrium condition that the aggregate supply of capital from investors equals the aggregate demand for capital from firms in the G and B sectors, and that the aggregate quantity of risk-free borrowing (or lending) is zero:

$$K_G = x\overline{w}_G + (1-x)w_{G,u}, \tag{15}$$

$$K_B = x\overline{w}_B + (1-x)w_{B,u}, \quad \text{and} \tag{16}$$

$$1 = w_{G,u} + w_{B,u}, \tag{17}$$

where the unconstrained investors' portfolio weights $w_{j,u}$ are given in Proposition 1.

Effective Mandate Pass-Through Ratio. To quantify the equilibrium effect of portfolio mandates, we introduce the concept of *effective mandate pass-through ratio*, a measure designed to capture the equilibrium impact of a portfolio mandate. We define the effective pass-through ratio as the fraction of the *intended* impact of a mandate that *survives* in general equilibrium, i.e.,

$$\text{Effective mandate pass-through ratio} := \frac{w_G^{\text{GE}} - w_G^*}{w_G^{\text{PE}} - w_G^*}. \tag{18}$$

In the definition above, w_G^* is the share of G capital in an economy *without* mandates (equal to 0.50 throughout this section because the G and B sector have the same risk and expected return). The quantity w_G^{GE} is the equilibrium share of G capital in an economy with mandates. The quantity w_G^{PE} is the share of G capital under the (partial equilibrium) assumption that unconstrained investors do not rebalance their portfolio in response to the imposition of a mandate, that is $w_G^{\text{PE}} := x \times \overline{w}_G + (1-x) \times w_G^*$. Hence, the effective mandate pass-through ratio in equation (18) measures the percentage of the *intended* impact of the mandate that is actually achieved in equilibrium.

There are two advantages of measuring the impact of mandates using the effective mandate pass-through ratio defined in equation (18). First, by scaling the actual mandate impact in the numerator by the intended mandate impact in the denominator, one can gauge more accurately what percentage of the mandate's intended impact is actually achieved. Second, this measure neutralizes, to a large extent, the effect of particular modeling choices because these affect not just the general equilibrium quantity in the numerator but also the partial equilibrium quantity in the denominator.

II.B. Results

The system of equations (15)–(17) defining an equilibrium does not admit a closed-form solution. In what follows, we analyze the equilibrium numerically, focusing on the effect of the return-to-scale parameter α. We consider an economy with two identical and independent technologies, G and B, with $\mu_{A_G} = \mu_{A_B} = 1.05$, $\sigma_{A_G} = \sigma_{A_B} = 0.2$, and $\rho = 0$. We assume that $x = 50\%$ of the investors face a mandate to invest $\overline{w}_G = 0.75$ of their savings in sector G and $\overline{w}_B = 0.25$ in sector B.[14] The quantities of interest obtained from the numerical solution are illustrated in Figures I and II. In these figures, the plots on the left refer to the case of low risk aversion, $\gamma_a = 2$, while the plots on the right refer to the case of high risk aversion, $\gamma_a = 5$.

Panel A of Figure I shows the portfolio weights of constrained and unconstrained investors. The dotted red line represents the portfolio weights of all investors if there were no mandates. Because the G and B technologies are identical, from equations (10)–(11) and the market clearing condition (17), we have that in the unconstrained economy each investor holds 0.50 in the G asset and 0.50 in the B asset, i.e., $w_G^* = w_B^* = 0.50$. When a fraction of investors are constrained by the portfolio mandate, their portfolio weights are displayed by the flat dashed lines: $w_{G,c} = \overline{w}_G = 0.75$ for the G asset and $w_{B,c} = \overline{w}_G = 0.25$ for the B asset. The solid green and brown lines represent the weights of the unconstrained investors, $w_{G,u}$ and $w_{B,u}$, respectively.

Panel B of Figure I reports the ratio of B vs. G expected returns, $\mathbb{E}[\tilde{R}_B]/\mathbb{E}[\tilde{R}_G]$. When $\alpha < 1$, the presence of a mandate that favors G increases the expected return of asset B relative to that of G. Consequently, in equilibrium, unconstrained agents rebalance away from G toward B, thus undoing part of the mandate, as shown in Panel A. When risk aversion is low (left plot), unconstrained investors are willing to hold a less diversified portfolio than when risk aversion is high (right plot). Hence, all else being equal, when risk aversion is low, the portfolio choice of unconstrained investors tends to undo more of the intended effect of the mandate.

Figure II shows the equilibrium sectoral capital allocation (Panel A), defined in equations (15)–(16), and the effective mandate pass-through ratio (Panel B), defined in equation (18). The equilibrium allocation of physical capital varies substantially with the returns-to-scale parameter, α. In particular, the mandate increases the allocation of capital to sector G relative to the benchmark

[14]Note that because $\overline{w}_G + \overline{w}_B = 1$, the constrained investors has zero holdings in the risk-free asset. Consequently, because of market clearing, the unconstrained investor also holds zero in the risk-free asset in equilibrium. Allowing for non-zero borrowing/lending has only a small effect on the results. Section OA.II of the Online Appendix considers this case.

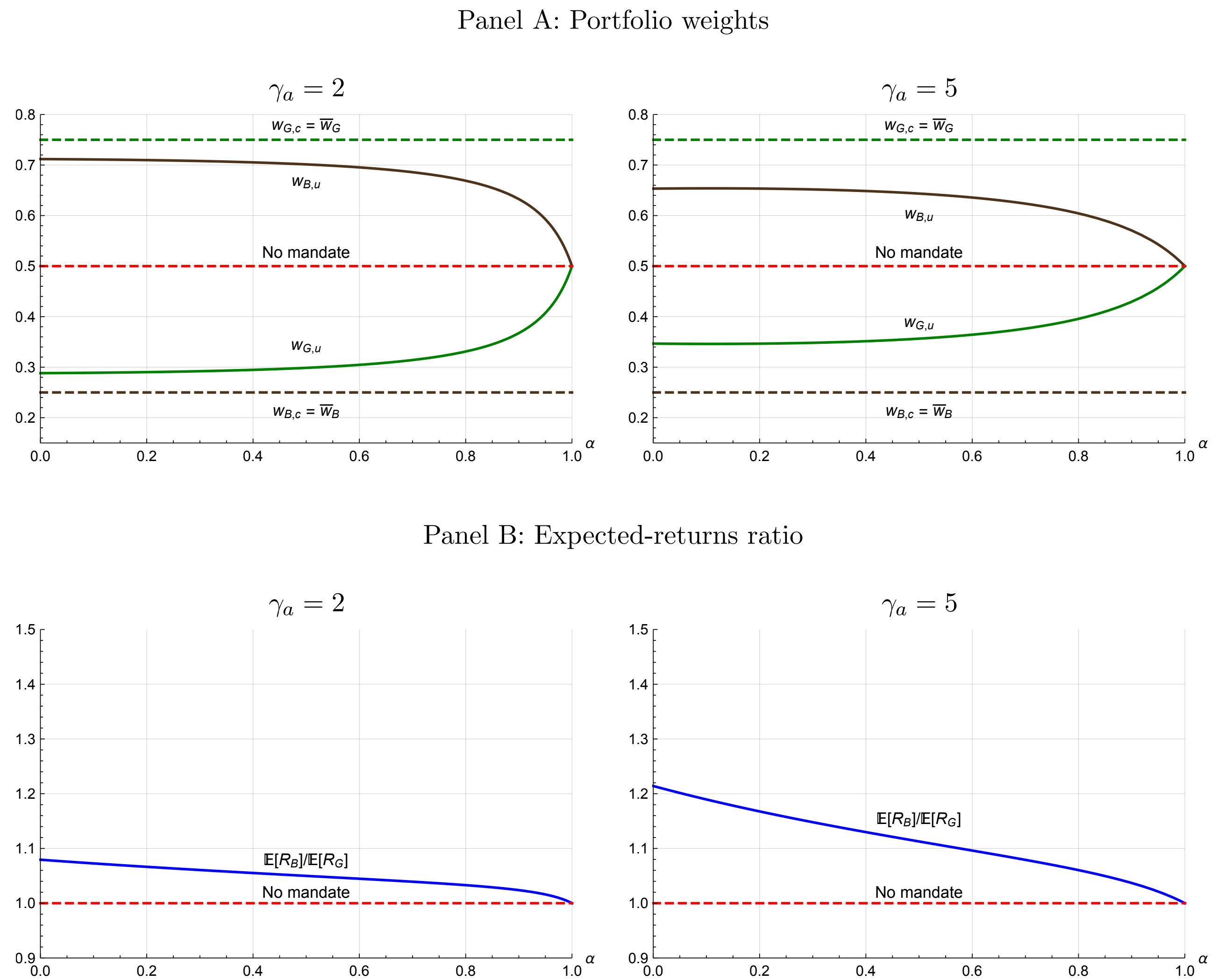

FIGURE I

Equilibrium portfolio weights and expected returns

Panel A shows the equilibrium portfolio weights of the unconstrained and constrained investors that are allocated to the G and B sectors. Panel B shows the ratio between equilibrium expected returns, $\mathbb{E}[\tilde{R}_B]/\mathbb{E}[\tilde{R}_G]$. The dashed red line represents the weights and expected returns in the absence of a portfolio mandate. In the panels on the left, investors' risk aversion is $\gamma_a = 2$, and in the right panels $\gamma_a = 5$. The other parameter values are: $\mu_{A_G} = \mu_{A_B} = 1.05$, $\sigma_{A_G} = \sigma_{A_B} = 0.2$, $x = 50\%$, $\overline{w}_G = 0.75$, $\overline{w}_B = 0.25$.

no-mandate case in which the allocation is 0.50 in each sector. The equilibrium capital allocation to sector G is closer to the no-mandate case for low values of risk aversion (left plot) and low values of α. With higher values of risk aversion (right plot), unconstrained investors have less of an incentive to deviate from the 50/50 diversified portfolio, and therefore, the mandate is more effective in influencing the equilibrium capital allocation in the economy (right plot).

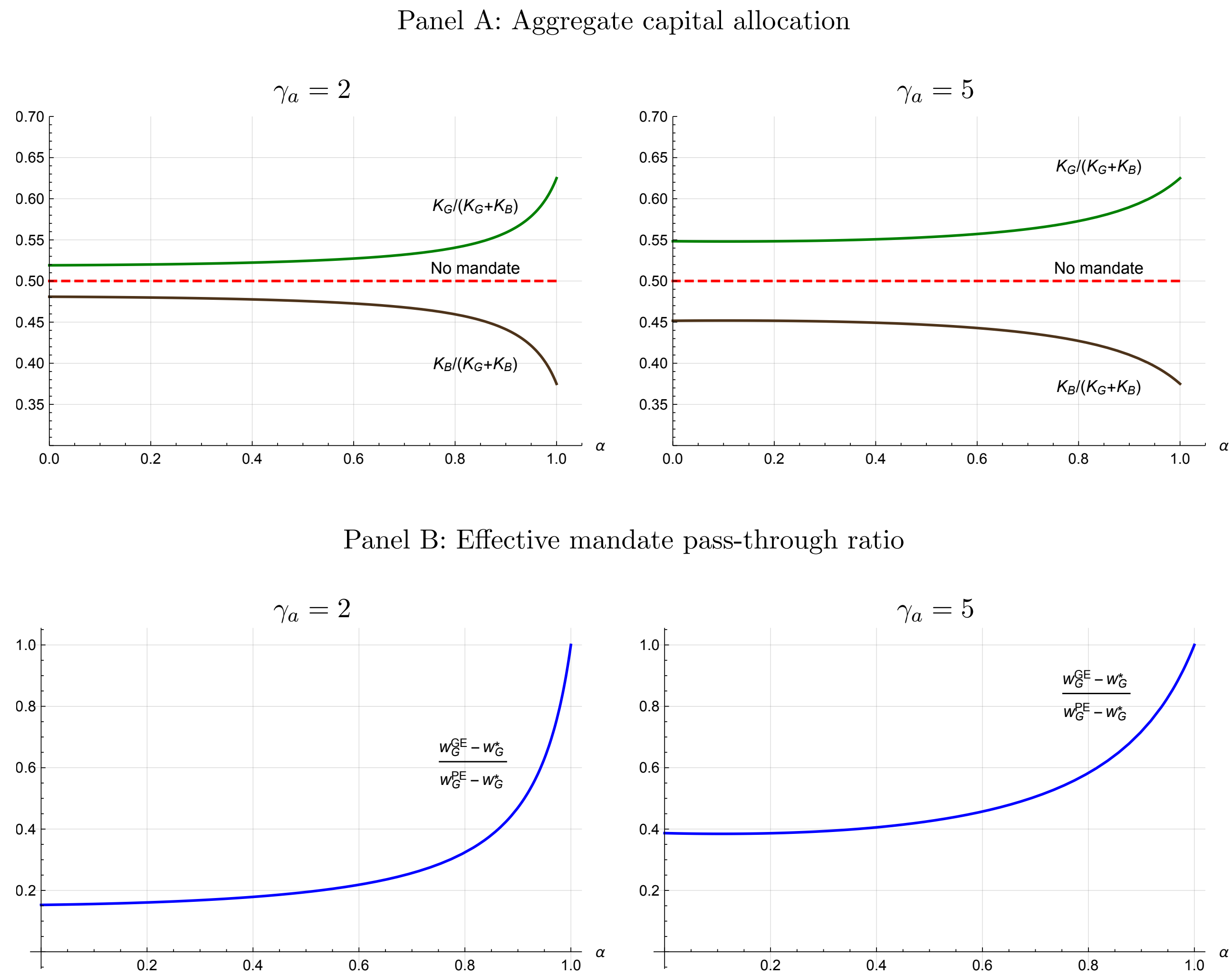

FIGURE II

Capital allocation and effective mandate pass-through ratio

Panel A shows the equilibrium capital allocation across sectors G (green line) and B (brown line) as a function of the returns-to-scale parameter, α. The dashed red line is the capital allocation without a portfolio mandate. Panel B shows the effective mandate pass-through ratio in equilibrium, defined in equation (18). In the plots on the left, investors' risk aversion is $\gamma_a = 2$, and in the plots on the right, $\gamma_a = 5$. The other parameter values are: $\mu_{A_G} = \mu_{A_B} = 1.05$, $\sigma_{A_G} = \sigma_{A_B} = 0.2$, $\rho = 0$, $x = 0.5$, $\overline{w}_G = 0.75$, $\overline{w}_B = 0.25$.

Panel B of Figure II shows the effective pass-through ratio. The mandate's effectiveness is small for low values of the returns-to-scale parameter α but can be substantial as α approaches 1, reaching a value of 100 percent when $\alpha = 1$. Risk aversion significantly impacts mandate effectiveness. All else being equal, a higher risk aversion (right plot) increases the pass-through because unconstrained investors are less willing to hold poorly diversified portfolios. However, risk aversion and, more generally, the elasticity of capital supply are irrelevant to the mandate's effectiveness when $\alpha = 1$.

In summary, Figures I and II show that to fully understand the effectiveness of portfolio mandates, it is essential to consider production models. Models without production, such as the endowment models of Heinkel et al. (2001) and Berk and van Binsbergen (2024), where output is exogenous, can lead to the inference that a low cost-of-capital spread also implies a negligible effect on the allocation of real capital across the G and B sectors, which is not true in general. As the case of constant returns to scale shows, the difference in returns can be zero, yet the mandate's real effect can be substantial. Thus, the difference in the cost of capital for firms in different sectors is not informative about the impact of a mandate. Instead, to properly assess the effectiveness of a mandate, one should directly measure the physical capital that is channeled to a sector as a result of the mandate.

II.C. Primary vs. Secondary Markets

One might think that trade in the secondary market would render our argument moot. For instance, a constrained investor could, upon facing a constraint, simply offer to trade G shares for B shares with an unconstrained investor, thereby satisfying the constraint without altering the physical quantity of capital. However, this argument overlooks the fact that such a transaction would make the unconstrained investor underdiversified and, therefore, this investor would demand a discount on the B shares.

Consider a scenario with no capital adjustment costs and constant returns to scale. In this case, the constrained investor can avoid the discount on selling B shares by directly shifting physical capital from sector B to G. This would allow the constrained investor to satisfy the mandate while keeping the unconstrained investor perfectly diversified.[15] Because there are no adjustment costs and returns to scale are constant, this capital shift would be costless, and the effective mandate pass-through ratio would be 100%. On the other hand, if there are decreasing returns to scale or capital adjustment costs, physically shifting capital becomes costly, resulting in less than a full pass-through. In Section III, we examine such more realistic cost scenarios.

[15] For example, constrained investors might be "activists" who pressure the brown firms they own to transition to green. Alternatively, they could raise financing for green firms, use those funds to purchase physical capital from brown firms, and then pay themselves a dividend from the proceeds, which would again reduce the physical capital in the brown sector.

III. A Multiperiod Equilibrium Model with Portfolio Mandates

In this section, we introduce portfolio mandates in a standard neoclassical general equilibrium model with production that we calibrate to match empirical macroeconomic and asset pricing moments for the US economy. When returns to scale are constant and there are no portfolio mandates, our model collapses to a canonical real-business-cycle model, similar to King et al. (1988), Jermann (1998), and many others.[16] We use this model to assess quantitatively the impact of portfolio mandates in equilibrium.

In the baseline version of the multiperiod model, we assume that the technologies for the firms in the G and B sectors are identical. In the absence of mandates, the equilibrium in this economy implies that each investor allocates an equal fraction of its risky portfolios to the two sectors. As a result, in equilibrium, capital is equally distributed between the G and B sectors. Portfolio mandates distort this allocation directly, through the portfolio constraint, and indirectly through the equilibrium effects on prices. Solving for the equilibrium in this economy allows us to assess the magnitudes of these distortions quantitatively. The analysis in this section highlights that the qualitative effects identified in the simple model of Section II are also quantitatively substantial. In particular, portfolio mandates can significantly impact the allocation of real capital even when the difference in the cost of capital in the two sectors is negligible. Finally, we also study the transition from an equilibrium without portfolio mandates to one with portfolio mandates. Our analysis highlights the relative importance of primary (real) markets and secondary (financial) markets during the transition, with the relative importance depending on capital adjustment costs and investors' risk attitudes.

III.A. Setup

Investors. We consider an infinite-horizon, overlapping generation (OLG) economy in discrete time $t = \{0, 1, \ldots\}$. The economy is populated by a continuum of measure-one "perpetual youth" investors with a per-period probability of survival p, following Blanchard (1985). When investors die, they are replaced by new investors whose wealth is the average of the wealth of both constrained and unconstrained deceased investors.[17] Investors hold equity shares of firms with one

[16] Specifically, our model is identical to King et al. (1988) if we set capital adjustment costs and the utility of leisure to zero, and is similar to Jermann (1998) with the only difference being the adjustment-cost specification: we use a quadratic adjustment cost function, as in Hayashi (1982), instead of an isoelastic function.

[17] Allowing for an OLG setup with such transfers helps with the stability of the numerical solution. Without this, the constrained investors' share of wealth can drift toward zero or one for long periods. We have experimented with

of two production technologies: G and B. A fraction x of investors are born constrained (c) and they stay constrained throughout their life. Constrained investors are subject to a portfolio mandate to hold the risky assets in a given fixed proportion. The remaining fraction $1-x$ of investors are unconstrained (u).

Let $W_{i,t}$, $C_{i,t}$, and $L_{i,t}$ represent, respectively, the net worth, consumption, and labor supply of investor $i = \{u, c\}$. Investors are endowed with one unit of labor that they supply inelastically, that is, $L_{i,t} = 1$ for all i and t for the wage ω_t. Let $B_{u,t+1}$ denote the face value at time $t+1$ of the one-period risk-free bond held by the unconstrained investors and by $R_{f,t}$ the risk-free rate; hence, $B_{u,t+1}/R_{f,t}$ represents the time t value of the holdings of the risk-free bond. We denote by $w_{G,i,t}$ and $w_{B,i,t}$ the share of savings (unconsumed wealth) of investor i that is invested in the G and B sectors, respectively. The cum-dividend time-t values of the G and B firms are, respectively, $V_{G,t}$ and $V_{B,t}$, with dividends $D_{G,t}$ and $D_{B,t}$.

We assume investors have Epstein-Zin recursive preferences with risk aversion γ, elasticity of intertemporal substitution ψ, and time-discount parameter β. The unconstrained investors solve

$$(19) \qquad U_u(W_{u,t}) = \max_{\{C_{u,t}, w_{G,u,t}, w_{B,u,t}\}} \left\{ C_{u,t}^{1-1/\psi} + p\,\beta \left(\mathbb{E}_t[U_u(W_{u,t+1})^{1-\gamma}] \right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}},$$

subject to the intertemporal budget constraint

$$(20) \qquad W_{u,t+1} = (W_{u,t} + \lambda \omega_t L_{u,t} - C_{u,t}) \left(R_{f,t} + w_{G,u,t}(R_{G,t+1} - R_{f,t}) + w_{B,u,t}(R_{B,t+1} - R_{f,t}) \right),$$

where the return $R_{j,t+1} = V_{j,t+1}/(V_{j,t} - D_{j,t})$, $j = \{G, B\}$, with $V_{j,t}$ and $D_{j,t}$ denoting firm j's value and dividends, defined below in equations (22) and (24). We also assume that some workers are "hand-to-mouth" and do not participate in financial markets. To model this, in the intertemporal budget constraint equation (20), labor income is given by $\lambda\, \omega_t L_{i,t}$, where λ represents the fraction of total labor income earned by equity investors. The rest of the labor income is earned by "hand-to-mouth" workers who play no role in the portfolio optimization problem. The optimality conditions for the problem (19)–(20) result in three standard Euler equations, one for each of the three financial assets, that is, the bond and the stocks for G and B firms.

The constrained investors' problem is identical to that of unconstrained investors, with the only difference being that constrained investors cannot choose their equity shares. Instead, they

alternative values for the probability of death, including probabilities very close to zero, and our key results on the effect of mandates are fairly insensitive to this parameter.

face a mandate to invest in the G and B sectors in given proportions, $\overline{w}_j \in (0,1)$, $j = \{G, B\}$.[18] As a result, the optimality conditions for constrained investors consist of a single Euler equation, characterizing the optimal consumption decision.

Firms. There are two types of firms, G and B, which make optimal hiring and investment decisions to maximize shareholders' value. As in a standard neoclassical model, we assume that firms incur convex capital-adjustment costs when making investment decisions (e.g., Hayashi, 1982). Firms are all-equity financed, with investors being the shareholders. Investors' consumption and portfolio decisions result in an aggregate supply of capital $K_{j,t}$, $j = \{G, B\}$ to the two sectors of the economy. Firms operate in a perfectly competitive market and produce identical goods but are subject to different productivity shocks.

Firms produce output $Y_{j,t}$ according to a Cobb-Douglas production function

$$Y_{j,t} = (K_{j,t})^{\alpha\theta}(A_{j,t}L_{j,t})^{(1-\theta)}, \tag{21}$$

where $\theta \in [0,1]$ controls the relative importance of capital in the production and $\alpha \in [0,1]$ is a returns-to-scale parameter. The production function exhibits constant returns to scale if $\alpha = 1$ and declining returns to scale if $\alpha < 1$. The quantity $A_{j,t}$ in equation (21) denotes a stochastic process representing neutral (TFP) productivity shocks. This shock may contain aggregate or firm-specific components; the aggregate component may have stationary and non-stationary components.

Firms choose labor $L_{j,t}$ and investment $I_{j,}$ to maximize shareholder value. Formally, firm j's value $V_{j,t}$ results from the solution of the following problem

$$V_{j,t}(K_{j,t}) = \max_{L_{j,t}, I_{j,t}} D_{j,t} + \mathbb{E}_t\left[\tilde{M}_{u,t+1}V_{j,t+1}(K_{j,t+1})\right], \tag{22}$$

where $\tilde{M}_{u,t+1}$ is the SDF of the unconstrained investors, who are the marginal investors in this economy. When maximizing shareholder value, firms take $\tilde{M}_{u,t+1}$ as given. The optimization in (22) is subject to the capital accumulation equation, which, using $\delta > 0$ to denote capital depreciation, is

$$K_{j,t+1} = (1-\delta)K_{j,t} + I_{j,t}. \tag{23}$$

[18] In our Baseline Economy, the constrained investor makes no portfolio choice at all because the share of the risk-free asset is simply equal to $1 - \overline{w}_{G,c} - \overline{w}_{B,c}$, which is fixed. We have also solved a version of the model where constrained investors can choose the risky vs. riskless share of the portfolio but are constrained as to the fraction of G vs. B assets within the risky portfolio. The results are quantitatively similar to our baseline case in Table IV, although the effective mandate pass-through ratio is slightly smaller.

As is well known, when $\alpha = 1$ the firm value $V_{j,t}(K_{j,t})$ can be written as $V_{j,t}(K_{j,t}) = K_{j,t} \times Q_{j,t}$, with $Q_{j,t}$ denoting Tobin's Q, or the market-to-book ratio. In the presence of adjustment costs, there is a wedge between the price of installed capital (firm value) and uninstalled capital (consumption), and therefore, Tobin's Q will, in general, be different from one.

Labor. In equation (22), $D_{j,t}$ represents the dividends firm j distributes to its shareholders. To define this quantity, we need to describe how wages are set in the model. If labor markets were perfectly flexible, the aggregate wage would be far too volatile, having the same properties as output; this would also counterfactually imply that profits and dividends are counter-cyclical and that equity volatility is too low. As shown by Favilukis and Lin (2016), introducing wage rigidity into a production-economy model makes wages, profits, and dividends behave more like in the data and improves the model's asset pricing performance. Because asset prices are crucial for our mechanism, we introduce wage rigidity in a reduced-form manner.

Specifically, we define $L_{j,t}$, $j = G, B$, the demand of labor in sector j at time t.[19] We assume that firms must hire at least labor $\overline{L}_j < L_{j,t} < 1$ at a rigid wage $\overline{\omega}_t$, but are free to choose how much remaining labor, $L_{j,t} - \overline{L}_j$, to hire, and that labor is paid a competitive wage $\tilde{\omega}_t$ that clears labor markets.[20] The average wage $\omega_{j,t}$ paid in each sector satisfies $\omega_{j,t} L_{j,t} = \overline{\omega}_t \overline{L}_j + \tilde{\omega}_t (L_{j,t} - \overline{L}_j)$. We set $\overline{L}_j \in (0, 1)$ to be equal to be a fraction $\overline{L}$ of the average unconditional labor in sector j, that is, $\overline{L}_j = \overline{L}\,\mathbb{E}[L_{j,t}]$. Because the aggregate labor supply is inelastic $L_{G,t} + L_{B,t} = 1$, this assumption implies that the average wage is $\omega_t = \omega_{G,t} = \omega_{B,t} = \overline{\omega}_t \overline{L} + \tilde{\omega}_t (1 - \overline{L})$, which, in equilibrium, is smoother than the competitive wage $\tilde{\omega}_t$. Note that the firm's first-order condition for investment is independent of $\overline{L}$; therefore, this reduced-form way of modeling wage rigidity does not affect the firm's investment choice. However, it does affect dividends, wages paid, firm value, and equity returns. Firm j's dividends are therefore given by

$$D_{j,t} = Y_{j,t} - \omega_t L_{j,t} - I_{j,t} - \eta \left(\frac{I_{j,t}}{K_{j,t}} - \hat{\delta} \right)^2 K_{j,t}, \quad \eta > 0,\ \hat{\delta} > 0, \tag{24}$$

[19]Note the slight abuse of notation, because in the definition of the household problem above we use $L_{i,t}$ to define the supply of labor for household $i = u, c$. The difference of the two contexts should not leave room for confusion.

[20]The rigid wage $\overline{\omega}_t$ is time-varying because, as we discuss below, productivity in our model grows at rate g. As we show in the Online Appendix, this implies that along the balanced growth path, most variables in the model grow at rate $\hat{g} = (1+g)^{\zeta} - 1$, where $\zeta := \frac{1-\theta}{1-\alpha\theta}$. Therefore, in the detrended version of the model, the rigid wage is constant and equal to the unconditional average of the detrended wage, which we define as $\overline{\omega} = \mathbb{E}[\hat{\omega}_t]$. However, because the economy is growing, the (non-detrended) rigid wage must grow too, that is, $\overline{\omega}_t = \overline{\omega}(1+g)^{\zeta t}$.

where $Y_{j,t}$ is output, defined in equation (21), and $\hat{\delta} := \delta + \hat{g}$ is capital depreciation, δ, gross of the growth rate along the balance growth path, $\hat{g} := (1+g)^{\frac{1-\theta}{1-\alpha\theta}} - 1$, as shown in the Online Appendix. The term $\eta \left(\frac{I_{j,t}}{K_{j,t}} - \hat{\delta} \right)^2 K_{j,t}$ in equation (24) represents a quadratic adjustment-cost function.[21]

Equilibrium. An equilibrium of this economy consists of (i) investors' consumption and portfolio policies, $\{C_{i,t}, w_{G,i,t}, w_{B,i,t}\}$; (ii) firms' investment and hiring policies, $\{I_{j,t}, L_{j,t}\}$; (iii) wages $\tilde{\omega}_t$; (iv) prices of the two risky assets, $\{V_{G,t}, V_{B,t}\}$, and the risk-free rate, $R_{f,t}$, such that: investors maximize their lifetime utility in equation (19), firms maximize shareholder value in equation (22), and the markets for labor, the two risky assets, and the risk-free asset clear. By Walras' law, the goods market automatically clears; i.e., the aggregate budget constraint holds.

III.B. Calibration

Choice of Parameter Values. We solve numerically for an equilibrium of the economy described above using dynamic programming; Section OA.I of the Online Appendix provides a detailed description of the numerical solution of the model. We calibrate the model parameters at an annual frequency to match key macroeconomic and asset pricing moments for two main economies; these parameter values are reported in Table I.

The first economy we study is labeled the "Baseline Economy," which, for expositional ease, is calibrated to have symmetry between the G and B sectors (when both investors are unconstrained), as well as symmetry between the constrained and unconstrained investors. Then, we study the effect of a portfolio mandate that requires 50% of investors to hold 75% of their wealth in the G sector and only 25% in the B sector. The second economy we study is labeled the "Current Green Economy," in which we calibrate the model to moments that approximately reflect the U.S. economy in 2010, a period that preceded significant discussions around portfolio mandates for green investments. Most parameter values remain identical to the Baseline Economy except for two changes. First, we set the fraction of constrained investors to be $x = 12.6\%$ and the fraction of their portfolio invested in green versus brown assets to be $(\overline{w}_G, \overline{w}_B) = (100\%, 0\%)$. We do this based on estimates inferred from the Global Sustainable Investment Alliance (2022) report.[22] Second, we set the fraction of green capital in the unconstrained economy to be $w_G^* = 73\%$

[21] Because we set gross depreciation to $\hat{\delta} = \delta + \hat{g}$, adjustment costs are zero in the steady state.

[22] In Appendix 1, p. 43 the Global Sustainable Investment Alliance (2022) report estimates that \$8.4tr out of \$66.6tr of professionally managed assets are subject to a sustainability mandate. This implies an estimate for x of

TABLE I

Parameter values

Parameter	Symbol	Baseline Economy	Current Green Economy
Investors			
Relative risk aversion (low, high)	γ	5, 75	5, 75
Elasticity of intertemporal substitution	ψ	0.20	0.20
Time discount rate	β	1.025	1.025
Survival probability	p	0.99	0.99
Fraction of constrained investors	x	0.50	**0.126**
Portfolio mandate	$(\overline{w}_G, \overline{w}_B)$	$(0.75, 0.25)$	**(1.0, 0.0)**
Faction of labor receiving fixed wage	$\overline{L}$	0.50	0.50
Fraction of labor income to investors	λ	0.25	0.25
Firms			
Aggregate growth rate	g	0.015	0.015
G TFP shock realization	(Z_L^G, Z_H^G)	$(0.912, 1.088)$	**(0.923,1.082)**
B TFP shock realization	(Z_L^B, Z_H^B)	$(0.912, 1.088)$	**(0.914,1.071)**
Probability of remaining in current state	q	0.82	0.82
Depreciation rate	δ	0.06	0.06
Capital adjustment cost	η	5.00	5.00
Parameter controlling the capital share	θ	0.35	0.35
Return to scale	α	1.00	1.00

Notes. The table reports the values for the two sets of parameters used to calibrate the multiperiod model described in this section. The first set of parameter values are for our "Baseline Economy" and the second set of parameter values are for the "Current Green Economy." The parameter values for the Current Green Economy that are different from those for the Baseline Economy are highlight in bold font.

by increasing the productivity of green assets and decreasing the productivity of brown assets. Together, these values imply that in the absence of general-equilibrium forces, the mandate would lead the share of green capital relative to total capital to increase from $w_G^* = 73\%$ to $w_G^{\text{PE}} = 76.4\%$ $(= 0.126 \times 1.0 + (1 - 0.126) \times 0.73)$.

Table I lists the parameter values used to calibrate the "Baseline Economy" and the "Current Green Economy." We consider two values for the coefficient of relative risk aversion. The first value is $\gamma = 5$ but we also solve the model with higher risk aversion, $\gamma = 75$. Although risk aversion $\gamma = 75$ is clearly unreasonable, we consider this case as a reduced-form way of capturing high risk premia in the economy arising from, e.g., habit in preferences, idiosyncratic labor income risk, taxes, and intermediary frictions. For example, Campbell and Cochrane (1999, p. 244) write that,

$8.4/66.6 = 12.6\%$. Pástor, Stambaugh, and Taylor (2023) construct a green-tilt measure of institutional holdings and estimate it to be about 6%.

"…we calculate risk aversion for our model. Risk aversion is about 80 at the steady state (twice the curvature of about 40), rises to values in the hundreds for low surplus consumption ratios, and is still as high as 60 at the maximum surplus consumption ratio."

We set the elasticity of intertemporal substitution (EIS) to $\psi = 0.2$ so that for the case of $\gamma = 5$, the investors' preferences are time-separable CRRA.[23] We set $\beta = 1.025$ to target a ratio of capital to output K/Y of around 2.9 in the steady state and an aggregate productivity growth rate of $g = 1.5\%$, which implies that most variables along the balanced growth path grow at a rate $\hat{g}$.[24] We set the probability of survival p to be 99% per period.

We set λ, which represents the fraction of total labor income earned by equity investors, to 0.25. To choose the value of λ, we proceed as follows. For each year in the Survey of Consumer Finances (available once every 3 years from 1986–2019), we sorted households from lowest to highest according to their equity investments (defined as the sum of IRAs, mutual funds, and directly held equity). We then identified equity investors by finding the holdings cutoff above which households jointly own 90% of all equity. On average, across all years, these households make up 10.2% of the population, but their labor income makes up $\lambda = 25.2\%$ of all labor income.

We choose parameters for the Markov chain describing the TFP process to match the volatility and autocorrelation of Hodrick-Prescott (H-P) filtered output.[25] Specifically, we assume that the firm's productivity is separated into aggregate and sector-level components: $A_t^j = A_t Z_t^j$. The aggregate component is deterministic, $A_t = (1+g)^t$, and captures the growth trend. The sector component Z_t^j is stochastic and drives the business cycle. We assume that the sector TFP shocks Z_t^j, $j = G, B$ are uncorrelated and follow a 2-state Markov chain with values Z_L^j and Z_H^j, with probability $q = 0.82$ of remaining in the current state.

We set the capital adjustment cost $\eta = 5$ to match a 3.25 ratio of aggregate investment volatility to aggregate output volatility. We set the fraction of labor receiving a fixed wage $\overline{L} = 0.50$ so that the volatility of wages is about half of that of output. This choice also implies reasonable values for the volatility and procyclicality of dividends and profits. We choose a depreciation

[23] Note that as we change risk aversion from $\gamma = 5$ to $\gamma = 75$, EIS is kept fixed. This explains why the macroeconomic moments in Table II are not sensitive to changes in risk aversion, see, e.g., Tallarini (2000).

[24] One may be concerned that with $\beta > 1$ equation (19) does not define a contraction mapping. However, note that we numerically solve the *detrended* model, which, as we show in the Online Appendix, is isomorphic to a model where there is no growth and the time discount factor is $\beta\, p\, (1+g)^{\zeta(1-1/\psi)}$, with $\zeta := (1-\theta)/(1-\alpha\theta)$. Hence, using $\beta = 1.025$ and the baseline parameters in Table I we have $\beta\, p\, (1+g)^{\zeta(1-1/\psi)} = 0.9561$.

[25] We use a filtering parameter of 100, as proposed by Backus and Kehoe (1992).

parameter $\delta = 0.06$, a standard value in the literature, and a capital share parameter $\theta = 0.35$ so that 65% of output is paid to labor.

We set returns to scale to be constant, i.e., $\alpha = 1.0$. Empirical estimates from the macroeconomics literature indicate that returns to scale are nearly constant in the US economy. Hall (1988, 1990) argues that market power and increasing returns to scale can explain procyclical productivity in the US. Subsequent work by Basu and Fernald (1997) estimates constant or slightly decreasing returns to scale but notes varying estimates at different industry levels, with typical industries showing decreasing returns while total manufacturing shows increasing returns.[26] In Section III.E, we allow for decreasing returns to scale.

It is well known that private-sector GDP is much more volatile than public-sector GDP. To capture this feature of the data, we allow for the existence of a government sector. We model the government in a stylized way by assuming that the actual amount of labor supplied by investors is 1.35 instead of 1.0, as described in the model section above, with 1.0 working in the private sector and 0.35 in the public sector. Public sector output requires only labor, and therefore, government labor equals government output. Unlike private-sector employees, public-sector employees are paid a constant wage adjusted for growth. That is, the government wage rate is set to $\overline{\omega}(1+\hat{g})^t$ where $\overline{\omega}$ is the unconditional average of the detrended market-clearing wage. Hence, total (detrended) government expenses are equal to $0.35 \times \overline{\omega}$ and total labor income is then $(\omega_t \times 1) + (\overline{\omega} \times 0.35)$. To ensure that the problem's solution is independent of government size, we assume that government expenditures are equal to a lump-sum tax levied on total labor income. Therefore, the only quantity affected by government expenditure is total GDP, which is equal to the sum of private-sector GDP and government expenditure. The choice of 1.35 for total labor implies that private sector GDP is about 80% of total GDP, as in the data.[27]

Macroeconomic Moments. Panel A of Table II compares macroeconomic moments in the data to corresponding quantities in the Baseline Economy with mandates, under the assumption that 50% of investors face a mandate to invest 75% of their wealth in firms in the G sector and 25% in the B sector. The values reported in the table are obtained by simulating the model

[26] Ahmad, Fernald, and Khan (2019) present new estimates for 1989-2014, finding constant or slightly decreasing returns to scale at the aggregate level but not ruling out increasing returns in specific industries or because of factors like technological progress. For instance, Way, Ives, Mealy, and Farmer (2022) argue that clean-energy technologies show increasing returns to scale because of learning curves.

[27] Note that, because the capital share $\theta = 0.35$, labor is approximately 65% of output, so if private labor is 1.0, then private output is 1.0/0.65=1.54. Government labor, which equals government output, is 0.35. Therefore, private output as a share of total output is 1.54/(1.54+0.35)=81%.

TABLE II
Macroeconomic moments

	Share of GDP			Volatility (%)			Corr with GDP			Autocorr		
	Data	Model		Data	Model		Data	Model		Data	Model	
		$\gamma = 5$	$\gamma = 75$		$\gamma = 5$	$\gamma = 75$		$\gamma = 5$	$\gamma = 75$		$\gamma = 5$	$\gamma = 75$
Panel A: Baseline Economy												
GDP	1.00	1.00	1.00	2.33	2.34	2.44	1.00	1.00	1.00	0.54	0.33	0.33
GDP-P	0.80	0.81	0.81	2.74	2.87	2.99	0.91	1.00	1.00	0.48	0.33	0.33
Consumption	0.63	0.63	0.62	1.72	1.57	1.60	0.91	0.99	0.99	0.53	0.34	0.34
Investment	0.17	0.17	0.19	7.60	7.53	7.59	0.78	0.99	0.99	0.45	0.33	0.33
Wages	—	—	—	1.17	1.44	1.50	0.49	0.99	1.00	0.58	0.34	0.33
Panel B: Current Green Economy												
GDP	1.00	1.00	1.00	2.33	2.34	2.44	1.00	1.00	1.00	0.54	0.33	0.33
GDP-P	0.80	0.81	0.81	2.74	2.87	2.99	0.91	1.00	1.00	0.48	0.33	0.33
Consumption	0.63	0.63	0.62	1.72	1.57	1.60	0.91	0.99	0.99	0.53	0.34	0.34
Investment	0.17	0.17	0.19	7.60	7.53	7.59	0.78	0.99	0.99	0.45	0.33	0.33
Wages	—	—	—	1.17	1.44	1.50	0.49	1.00	1.00	0.58	0.34	0.33

Notes. This table shows the macroeconomics moments for two economies—the "Baseline Economy" and the "Current Green Economy," and compares them to the corresponding quantities computed using the Bureau of Economic Analysis (BEA) data. All variables, other than the Share of GDP, are H-P filtered. Volatility is in annual percentage units. GDP-P refers to private sector GDP. The values in the "Model" columns for the "Baseline Economy" in Panel A are obtained by solving a version of the model with a portfolio mandate that constrains 50% of investors to invest 75% of their wealth in firms in the G sector and 25% in firms in the B sector. The values in the "Model" columns for the "Current Green Economy" in Panel B are obtained by solving a version of the model with a portfolio mandate that constrains 12.6% of investors to invest 100% of their wealth in firms in the G sector and 0% the B sector. The models are calibrated at an annual frequency. Parameter values for the two models considered in this panel are reported in the last two columns of Table I.

for 10,000 years and using a 100-year burn-in period. The table reports five quantities: total GDP, private-sector GDP (GDP-P), Consumption, Investment, and Wages. For each quantity, we compute the share of GDP, the volatility, the correlation with GDP, and the autocorrelation and compare them to the corresponding values in the data. The table shows that the model matches key macroeconomic moments reasonably well under the baseline parameters given in Table I. The only moments significantly different from the data are the correlations of investment and wages with GDP, which, in the data, are much smaller than in the model. This is not surprising because, with two sectoral shocks, the model correlation with GDP tends to be close to 1.

Panel B of Table II compares macroeconomic moments in the data to corresponding quantities in the Current Green Economy with mandates, under the assumption that 12.6% of investors face a mandate to invest 100% of their wealth in firms in the G sector and 0% in the B sector. We see that the macroeconomic moments are very similar to those in Panel A. We also solve and

TABLE III

ASSET PRICING MOMENTS

		Model	
	Data	$\gamma = 5$	$\gamma = 75$
Panel A: Baseline Economy			
$\mathbb{E}[R_f]$	0.91	5.68	1.97
$\sigma(R_f)$	2.27	3.35	3.79
$\mathbb{E}[R^M - R_f]$	8.99	1.70	8.46
$\sigma(R^M - R_f)$	17.89	16.90	18.00
Panel B: Current Green Economy			
$\mathbb{E}[R_f]$	0.91	5.75	2.38
$\sigma(R_f)$	2.27	3.22	3.66
$\mathbb{E}[R^M - R_f]$	8.99	1.60	7.48
$\sigma(R^M - R_f)$	17.89	16.64	16.28

Notes. This table shows the annual mean and volatility of the risk-free rate, $\mathbb{E}[R_f]$ and $\sigma(R_f)$, and of the market risk premium, $\mathbb{E}[R^M - R_f]$ and $\sigma(R^M - R_f)$. Values in the Data column are based on the sample period 1950–2021 and are from Ken French's website. Moments of the risk-free rate, R_f, refer to the real risk-free rate, which is obtained using the GDP deflator from BEA. The model moments reported in Panel A are for our Baseline Economy, which has a portfolio mandate that constrains 50% of investors to invest 75% of their wealth in firms in the G sector and 25% in firms in the B sector. The moments reported in Panel B are for the Current Green Economy, which has a portfolio mandate that constrains 12.6% of investors to invest 100% of their wealth in firms in the G sector and 0% in firms in the B sector. In each panel, we report the moments for two values of relative risk aversion: $\gamma = 5$ and $\gamma = 10$. The model is calibrated at an annual frequency. Parameter values for the two models considered in Panels A and B are reported in Table I.

study several models that are variations of the Baseline Economy in Section III.E. For all these models, too, the macroeconomic moments are very similar to the ones presented in Table II so are not reported.

Asset-Pricing Moments. Table III reports four asset pricing moments: the annual mean and volatility of the risk-free rate and of the equity-market risk premium. Panel A presents results for the Baseline Economy and Panel B for the Current Green Economy, in each case for two levels of risk aversion: $\gamma = 5$ and $\gamma = 75$. The equity return used to compute the market risk premium is levered using a factor of two, equivalent to an economy-wide 50/50 debt-to-equity ratio, see, e.g., Croce (2014). Note that even though we assume that the TFP shocks for the G and B sectors are uncorrelated, equity returns in the two sectors have a correlation of about 0.82 in the Baseline Economy and 0.84 in the Current Green Economy, similar to the values observed in the data.

Table III shows that the model does a good job of matching the volatility of the risk-free rate and of the equity risk premium in the data. However, not surprisingly, for the case of low risk aversion, $\gamma = 5$, the risk-free rate is too high, and the equity risk premium is too low. This is just a manifestation of the equity-premium puzzle. With a risk aversion of $\gamma = 75$, the equity premium and risk free rate are closer to the data.

Table IV contains our results on the effectiveness of mandates for two levels of risk aversion: $\gamma = 5$ and $\gamma = 75$. The first column of this table shows the capital allocation to the green sector in an economy without mandates (w_G^*). The second column reports the intended mandate impact in partial equilibrium ($w_G^{\text{PE}} - w_G^*$). The third and fourth columns report the actual impact in general equilibrium ($w_G^{\text{GE}} - w_G^*$). The fifth and sixth columns report the effective mandate pass-through ratio, defined in equation (18). The last two columns of the table report the difference in the cost of capital spread between the B and G sectors, $R^c_{BMG} - R^*_{BMG}$, with R^c_{BMG} denoting the spread in an economy with mandates and R^*_{BMG} the spread in the corresponding economy without mandates.

The first row in Table IV refers to the Baseline Economy, whose results are discussed in Section III.C below. The second row refers to the Current Green Economy, whose results are discussed in Section III.D. The remaining five rows refer to alternative economies that are variations of the Baseline Economy and are discussed in Section III.E.

III.C. Results for the Baseline Economy

In the Baseline Economy, whose parameters are listed in the penultimate column of Table I, the technologies of firms in the two sectors are identical. Hence, in the absence of mandates, the equilibrium fraction of capital allocated to G is $w_G^* = K_G^*/(K_G^* + K_B^*) = 0.50$, which is the number reported in the first column of Table IV. When half of the investors ($x = 0.5$) are subject to a mandate that requires them to invest 75% in the G sector ($\overline{w}_G = 0.75$), then the intended mandate impact is $w_G^{\text{PE}} - w_G^* = 12.5\%$, reported in the second column. The third and fourth columns of Table IV show that the actual pass-through impact in general equilibrium is 7.63% for risk aversion $\gamma = 5$ and 14.3% for $\gamma = 75$. This implies that the share of G capital rises from $w_G^* = 50\%$ to $w_G^{\text{GE}} = 57.63\%$ when risk aversion is $\gamma = 5$, and to 64.3% when risk aversion is $\gamma = 75$, and that the effective mandate pass-through ratios are 61% and 114.4%, respectively. This shows that, even in the case of low risk aversion, although general-equilibrium effects undo part of the mandate, a significant part remains effective. Intuitively, by increasing the cost of capital of firms in the B

TABLE IV

EQUILIBRIUM EFFECTS OF PORTFOLIO MANDATES

	w_G^* (%)	$w_G^{PE} - w_G^*$ (%)	$w_G^{GE} - w_G^*$ (%)		Pass-through (%)		$R_{BMG}^c - R_{BMG}^*$ (bps)	
			$\gamma = 5$	$\gamma = 75$	$\gamma = 5$	$\gamma = 75$	$\gamma = 5$	$\gamma = 75$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Baseline Economy	50.0	12.50	7.63	14.3	61.0	114.4	2.4	7.3
Current Green Economy	73.0	3.40	1.61	5.60	47.6	164.7	1.3	1.0
Alternative Economies								
1. No hand-to-mouth workers	50.0	12.50	3.93	10.38	31.4	83.0	1.0	10.0
2. Decreasing return to scale	50.0	12.50	3.00	10.98	24.0	87.8	8.4	28.9
3. Fewer constrained investors	50.0	6.25	3.07	7.10	49.1	113.6	3.6	8.9
4. More concentrated mandate	50.0	12.50	5.78	12.28	46.2	98.2	5.7	10.1
5. Higher share of green capital	73.0	7.25	4.41	8.88	60.8	122.5	3.0	0.9

Notes. The table shows the capital allocation to the green sector in an economy without mandates (w_G^*), the intended mandate impact in partial equilibrium ($w_G^{PE} - w_G^*$), the actual mandate impact in general equilibrium ($w_G^{GE} - w_G^*$), the effective mandate pass-through ratio (Pass-through), defined in equation (18), and the difference in the cost of capital spread between the B and G sector, $R_{BMG}^c - R_{BMG}^*$, with R_{BMG}^c denoting the spread in an economy with mandates that constrain the portfolios of some investors and R_{BMG}^* the spread in an otherwise unconstrained economy (i.e., without mandates). The quantities reported for the "Baseline Economy" and the "Current Green Economy" are obtained using the parameters reported in the last two columns of Table I. The "Current Green Economy" is calibrated to capture representative moments of the US economy in 2010 (see Section III.D for details). In Economy 1, we assume all workers are investors ($\lambda = 1$) and there are no "hand-to-mouth" workers. In Economy 2, we consider the case of decreasing returns to scale ($\alpha = 0.975$). In Economy 3, the mass of constrained investors facing the mandate is only 25% instead of 50%, with constrained investors mandated to hold 75% of their wealth in green assets. In Economy 4, constrained investors represent only 25% of the entire population, but now they are mandated to hold 100% of their wealth in green assets. In Economy 5, the unconstrained economy is one where the G capital share is 73%, consistent with Berk and van Binsbergen (2024), and investors are mandated to hold 87.5% in green assets.

sector, the mandate makes them more attractive to unconstrained investors who trade off higher returns for worse diversification. As risk aversion increases, the mandate's impact is larger because the unconstrained investors are less willing to deviate from the well-diversified unconstrained 50/50 allocation in response to the increase in risk-premium in the B sector. Note that a 7.63% increase in green capital is a substantial effect, as highlighted by Hong, Karolyi, and Scheinkman (2020, p. 1012) who report that: "The European Commission estimates that energy and infrastructure investments, mainly from the private sector, would have to rise to 2.8% of European Union gross domestic product (GDP) from 2% today (or an additional $376 billion annually) to reduce EU net greenhouse gas emissions to zero by midcentury."

The last two columns of Table IV report the effect of mandates on the firms' cost of capital in the Baseline Economy. Unlike the significant values for the mandate impact in columns (3) and (4), the effect on the cost of capital is minimal. Recall that for the baseline economy without mandates $R^*_{BMG} = 0$, and therefore the difference $R^c_{BMG} - R^*_{BMG}$ is exactly the difference in the cost of capital between the B and G sectors in the economy with mandates. In the baseline economy, when $\gamma = 5$, this spread is 2.4 basis point. This negligible difference in the cost of capital contrasts with the significant effective mandate pass-through ratio of 61% reported in column (5). The contrast between the mandate's "real" and "financial" effects is even more striking when risk premia are closer to their value in the data ($\gamma = 75$). In this case, the difference in the cost of capital under constant returns to scale is 7.3 basis points, while the effective mandate pass-through ratio is 114.4%.

We now explain why, when $\gamma = 5$, unlike the single-period model of Section II, the effective mandate pass-through ratio for $\alpha = 1$ is less than 100%. The main reason is investors' desire to hedge labor income risk. If constrained investors overweight G assets and the unconstrained investors do not fully offset this by overweighting B assets, then the overall output in the economy would become more correlated with shocks to G than with shocks to B. Because in the Baseline Economy, labor income is perfectly correlated with output, it would also become more correlated with G shocks. Thus, unconstrained investors/workers can hedge labor income risk by overweighting asset B, which then reduces the effectiveness of the mandate.

Finally, note that the pass-through is larger than 100% for $\gamma = 75$. This is because when risk aversion is high, G assets earn lower returns relative to B and, therefore, to satisfy the precautionary demand for savings, constrained investors need to save more wealth. Consequently, the share of aggregate savings of the constrained investor increases, leading to a larger aggregate investment in G assets and, therefore, a larger effective mandate pass-through ratio.

In summary, the quantitative results from our Baseline Economy support the central intuition developed in the simple model of Section II. Specifically, in an economy with production, mandates can have a quantitatively significant impact on capital allocation despite having a negligible effect on firms' cost of capital. These findings caution against using the cost of capital to measure the effectiveness of portfolio mandates in equilibrium; instead, one should measure the flow of capital induced by a mandate and the resulting effect on the value of green and brown firms.

III.D. Results for the Current Green Economy

For expositional ease, the Baseline Economy in Table IV is calibrated to have symmetry between the G and B sectors (when both investors are unconstrained), as well as the constrained and unconstrained investors. In this section, we calibrate the economy to moments that approximately reflect the U.S. economy in 2010, a period that preceded significant discussions around portfolio mandates for green investments. We refer to this model as the "Current Green Economy" and the parameter values for this model are given in the last column of Table I.

As explained in Section III.B, most parameters for the Current Green Economy remain identical to the Baseline Economy, except for two changes. First, the fraction of constrained investors is $x = 12.6\%$ and the fraction of their portfolio invested in green versus brown assets to be $(\overline{w}_G, \overline{w}_B) = (100\%, 0\%)$. Second, the fraction of green capital in the unconstrained economy is $w_G^* = 73\%$. These two values then imply that, in the absence of general-equilibrium forces, the mandate would lead the share of green capital relative to total capital to increase by 3.40, from $w_G^* = 73\%$ to $w_G^{\text{PE}} = 76.4\%$ $(= 0.126 \times 1.0 + (1 - 0.126) \times 0.73)$. These two numbers are reported in Columns (1) and (2) of Table IV for the row labeled Current Green Economy.

When risk aversion $\gamma = 5$, we see from Column (3) of Table IV that the share of green capital in equilibrium increases by 1.61% from 73% to 74.61%, implying an effective mandate pass-through ratio of 47.6%. This is quantitatively similar to the Baseline Economy but is slightly weaker because the mandate is more concentrated, i.e., it applies to a smaller proportion of investors. When risk aversion is $\gamma = 75$, the share of green capital increases by 5.6% from 73% to 78.6%, implying a pass-through of 164.7%. As in the case of the Baseline Economy, differences in the cost of capital remain small—about one basis point.

III.E. Results for Alternative Economies

The analysis of the five alternative economies in Table IV provides deeper insights into the economic mechanisms that can enhance or diminish the effectiveness of mandates in equilibrium.

In Economy 1, we assume that, unlike the Baseline Economy, there are no "hand-to-mouth" workers who do not participate in financial markets. To do so, in the term $\lambda\,\omega_t L_{i,t}$ in the intertemporal budget constraint (20), we set $\lambda = 1$, which represents the fraction of total labor income earned by equity investors. The absence of hand-to-mouth workers reduces the mandate pass-through ratio, which is now roughly half that of the Baseline Economy. The mandate intends to make the G sector larger. When unconstrained investors are also workers, they hold the B asset to hedge, thereby "undoing" some of the mandate's effect on the share of G capital. This hedging motive is particularly strong when all workers are investors, as in this parameterization. As a result of all workers being investors, we observe more "undoing" of the mandate, leading to a decrease in the effective mandate pass-through ratio.

In Economy 2, we consider the case of a decreasing returns-to-scale production technology, in which we replace $\alpha = 1$ with $\alpha = 0.975$, based on the estimate in Binsbergen and Opp (2019, table II). Consistent with the main intuition from the simple model of Section II, in an economy with decreasing returns to scale, the pass-through is significantly smaller than the Baseline Economy with constant return to scale ($\alpha = 1$). The decrease in the pass-through ratio is more substantial when risk aversion is low ($\gamma = 5$) than when it is high ($\gamma = 75$).

Economies 3 and 4 explore the effect of mandate design. Specifically, in Economy 3, we assume that the mass of constrained investors is smaller ($x = 25\%$) than in the Baseline Economy ($x = 50\%$) and $\overline{w}_G = 0.75$, as in the baseline economy. In the economy with fewer constrained investors (Economy 3), relative to the Baseline Economy, the intended mandate impact $w_G^{\text{PE}} - w_G^*$ drops from 12.5% to 6.25%.[28] In Economy 4, we consider the case of a more "concentrated" constraint, i.e., we reduce the mass of constrained investor from $x = 50\%$ to $x = 25\%$ but we assume that each has to hold $\overline{w}_G = 100\%$ of their wealth in the G asset, as opposed to $\overline{w}_G = 75\%$ in the Baseline Economy. In the economy with the concentrated constraint, the amount of excess capital committed to the green assets is the same as in the baseline economy because $w_G^{\text{PE}} - w_G^* = 0.125$.[29] The results in Table IV for these two alternative economies show that both modifications reduce the effectiveness of the mandate for both levels of risk aversion. In the economy with fewer constrained investors (Economy 3), the general equilibrium pass-through $w_G^{\text{GE}} - w_G^*$ drops from 7.63% to 3.07% for the case of $\gamma = 5$ and from 14.3% to 7.10% for the case of $\gamma = 75$. Because the mass of constrained investors is smaller, less capital flows to the G sector. In the economy with a more concentrated constraint (Economy 4) the intended mandate impact $w_G^{\text{PE}} - w_G^*$ is the same as in the baseline economy, that is, 12.5%. However, the general equilibrium pass-through $w_G^{\text{GE}} - w_G^*$ drops from 7.63% to 5.78% for the case of $\gamma = 5$ and from 14.3% to 12.28% for the case of $\gamma = 75$.

[28] In Economy 3, if only 25% of investors are constrained (instead of the 50% in the Baseline Economy) to invest 75% in G assets, then we have $w_G^{\text{PE}} - w_G^* = 0.25 \times 0.75 + 0.75 \times 0.5 - 0.5 = 0.0625$.

[29] Specifically, in Economy 4 with the "concentrated" mandate, we have $w_G^{\text{PE}} - w_G^* = 0.25 \times 1.0 + 0.75 \times 0.5 - 0.5 = 0.125$, just as in the baseline economy we have $w_G^{\text{PE}} - w_G^* = 0.5 \times 0.75 + 0.5 \times 0.5 - 0.5 = 0.125$.

The reason for this drop is that in an economy with a concentrated constraint there is a larger fraction of unconstrained investors who offset the effect of the mandate by increasing their share of wealth in B assets. This result highlights the importance of imposing a mandate on a broader set of investors.

In Economy 5, we consider a benchmark unconstrained economy in which the share of green capital is set to $w_G^* = 73\%$, following the estimated value reported in Berk and van Binsbergen (2024), but leave all other parameter values as in the baseline economy.[30] We consider a mandate imposed on 50% of investors that requires them to invest 87.5% in G assets and 12.5% on B assets. Thus, the intended mandate impact in partial equilibrium is $73 \times 0.50 + 87.5 \times 0.50 = 80.25\%$ so that $w_G^{\mathrm{PE}} - w_G^* = 7.25$. The result in Table IV confirms that this alternative benchmark has a negligible effect on the effective mandate pass-through ratio in equilibrium relative to the case of the Baseline Economy. Specifically, the effective mandate pass-through ratio changes from 61% in the Baseline Economy to 60.8% for the case of $\gamma = 5$ and from 114.4% to 122.5% for the case of $\gamma = 75$.

In sum, the overall message from the analysis in Table IV is that, across several alternative specifications of the economy, mandates can have significant capital allocation impact, as emphasized by the values of the equilibrium pass-through, while affecting only negligibly the equilibrium cost of capital across sectors. In particular, we find that the pass-through is stronger when investors are more risk averse, when the proportion of investors facing the mandate is larger, when the mandate is spread over a larger proportion of investors, when returns to scale are high, and when investors' labor income is less correlated with investment income.

III.F. Transition Dynamics

So far, the analysis has compared unconditional averages across steady states. To understand the mechanism through which mandates achieve their goal, in this section, we study the transition dynamics upon the imposition of a mandate on a fraction of investors.

We start from the average steady state of the Current Green Economy with only unconstrained investors. Specifically, we set the green share of capital to be 0.73 and the total capital to

[30] To achieve $w_G^* = 73\%$ in the unconstrained economy, we increase the productivity of the green sector and simultaneously decrease that of the brown sector while keeping average productivity at 1. We also reduce the spread between the high and low states of the Markov chain for Z_t^j to match the volatility of GDP. The corresponding values of the Markov chain for the green and brown TFP are identical to "Current Green Economy" values reported in the last column of Table I.

be equal to the unconditional average of the unconstrained model. We then assume that 12.6% of investors are required to satisfy a portfolio mandate that requires them to hold only green assets, i.e., $(\overline{w}_G, \overline{w}_B) = (100\%, 0\%)$. We then simulate the model for 100 years using policy functions from the constrained version of the economy. We assume that the imposition of a mandate is an unanticipated "shock", frequently referred to in the literature as an "MIT shock."[31]

Figure III shows the transition dynamics for three quantities: the green share of aggregate physical capital (Panel A), the effective mandate pass-through ratio (Panel B), and the green share of unconstrained investors' portfolio (Panel C). The two flat dotted lines in Panel A refer to the steady state green capital share in the constrained economy. For risk aversion 5 (red-black dotted line), the steady state is 74.61%, and for risk aversion $\gamma = 75$ (blue dotted line), the steady state is 78.60%.[32] The three upward-sloping lines in Panel A, drawn for different combinations of risk aversion and capital adjustment costs, show how these two forces influence the transition to a more green economy.[33] Unconstrained investors trade off the diversification benefits of a fast transition versus the adjustment costs. As expected, the larger the adjustment costs, the slower the transition to the steady state. This can be seen by comparing the black solid line, where adjustment costs are high, to the red dotted line, where adjustment costs are lower.

Similarly, comparing the solid black and red dotted lines in Panel B, we see that the effective mandate pass-through ratio is much smaller when adjustment costs are higher. In the short run, adjusting the scale of capital is costly, and consequently, investors facing the mandate find it optimal to satisfy it by rebalancing their portfolio in the secondary market.

Panel C illustrates this portfolio rebalancing by showing that, upon the imposition of the mandate, there is a substantial decrease in the share of the unconstrained investors' portfolio invested in the green sector to accommodate the increase in demand for green assets from the 12.6%

[31] Specifically, we start the productivity process in each of the four possible TFP realizations. For each of the four initial realizations, we run 500 simulations for 100 years. In each simulation, the realized TFP shocks are random. We then compute the average across all simulations and all initial realizations.

[32] The steady-state quantities for the Current Green Economy can be obtained from the second row of Table IV. Column (1) of this table shows that the proportion of capital in the G sector before the mandate is 73% while columns (3) and (4) show that the effect of the mandate is to increase capital in the G sector by 1.61% for the case of $\gamma = 5$ and by 5.60% for $\gamma = 75$.

[33] As discussed in Table I and Section III.B, the adjustment cost in the Baseline Economy is $\eta = 5$ and is calibrated to match the ratio of aggregate investment volatility to aggregate output volatility, which is 3.25. In the model with lower costs, we set $\eta = 1.5$, which implies a ratio of 3.7. In principle, this parameter may also depend on the industry or the type of sanction. For example, after Russia's invasion of Ukraine in 2022, many firms exited Russia, leaving all of their physical capital behind and receiving zero compensation. Thus, they were unable to shift any physical capital out of Russia. In this case, the long-term steady state will be reached only through the depreciation of assets in Russia and the simultaneous building up from scratch of assets outside of Russia.

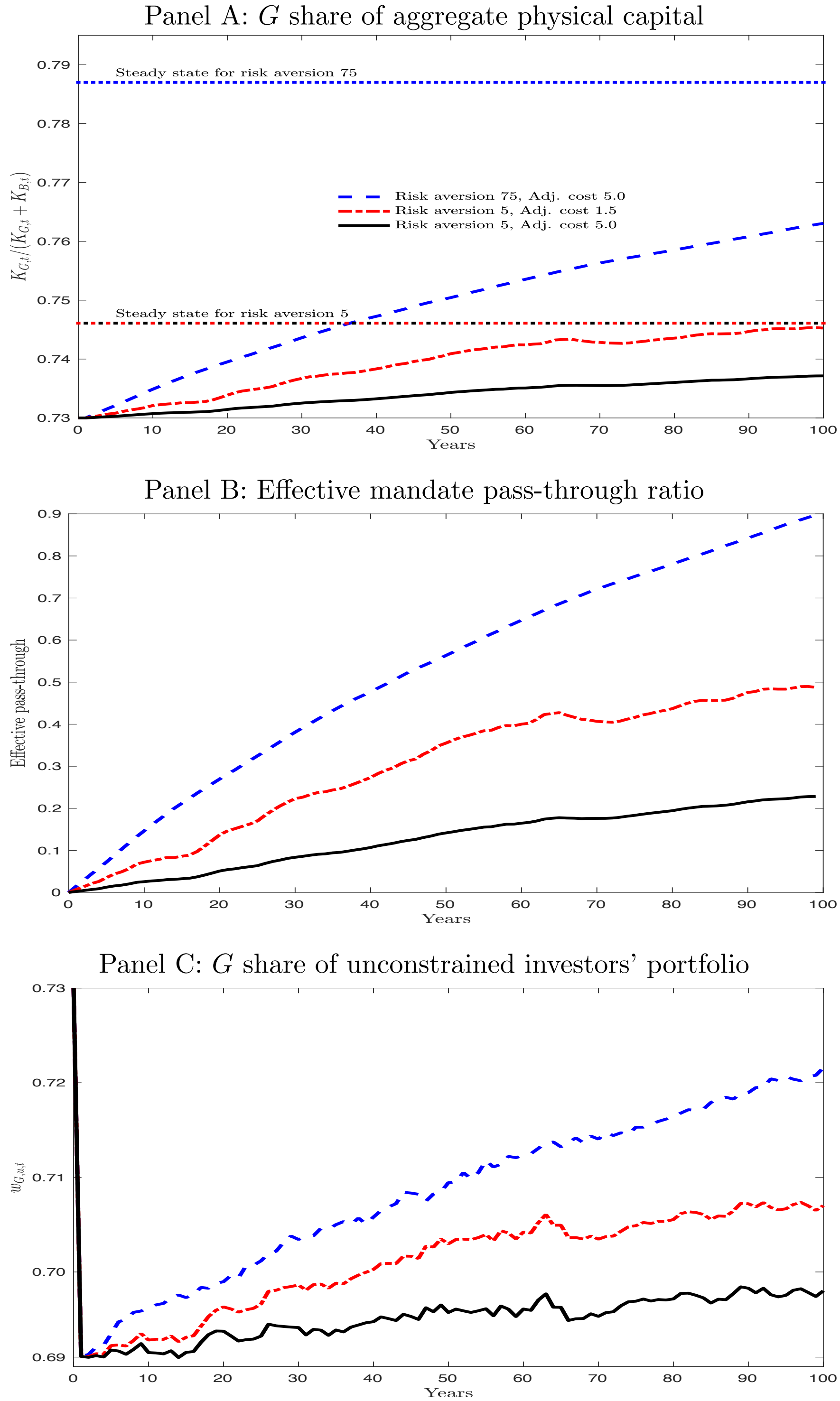

FIGURE III

Dynamics of green transition

Panel A of the figure shows the dynamics of the green share of aggregate physical capital, $K_{G,t}/(K_{G,t}+K_{B,t})$, Panel B shows the effective mandate pass-through ratio, and Panel C shows the green share of unconstrained investors' portfolio, following the imposition of a portfolio mandate at time 0. Specifically, we set the wealth of constrained investors to be $x = 0.126$, the share of green capital to be 0.73, and the total capital equal to the unconditional average of the unconstrained model. We start the productivity process in each of the four possible TFP realizations. For each of the four initial realizations, we run 500 simulations for 100 years. In each simulation, the realized TFP shocks are random. We then compute the average across all simulations and all initial realizations.

of investors facing the mandate to invest 100% in G assets. Before the shock, all investors were unconstrained, and their portfolio share in the green asset was approximately 73%, i.e., the green share of aggregate physical capital.[34] Upon the imposition of the mandate, the unconstrained investors' share falls significantly to approximately 69% to accommodate the jump in the constrained investors' portfolio. If unconstrained investors were to do nothing in the secondary market, then to satisfy the mandate, a significant fraction of physical capital would immediately shift from the brown to the green sector, thus incurring enormous adjustment costs. However, over time, the aggregate capital stock does respond to the mandate (Panel A), the effective mandate pass-through ratio increases (Panel B), and consequently, the unconstrained investors' share of green assets in their portfolio rises, eventually reaching its long-term stochastic steady state (Panel C).

When investors are more risk-averse, unconstrained investors are less willing to accommodate the increase in portfolio demand for green assets from constrained investors. Consequently, the mandate is much more effective in shifting physical capital from the brown to the green sector. This can be seen by comparing the blue dashed line (for risk aversion equal to $\gamma = 75$) to the black solid line (for risk aversion equal to 5), where both lines are drawn for the same level of capital adjustment cost.

Finally, for all cases considered, the impact of the mandate on the cost of capital in the green and brown sectors along the transition path remains negligible (the results are not reported), consistent with the cost of capital spreads across the green and brown sectors reported in columns (7) and (8) of Table IV.

IV. Conclusion

In this paper, we investigate the impact of portfolio mandates on the allocation of physical capital in a general-equilibrium production economy with heterogeneous investors. Unlike previous studies that have primarily focused on endowment economies, we consider a production economy, which allows us to explicitly capture the interactions between capital allocation and asset returns.

Our analysis reveals that portfolio mandates can significantly influence the allocation of capital across sectors, even when the differences in the cost of capital are negligible. This finding

[34] The portfolio shares are not exactly equal to 73% because the market-to-book ratios of the green and brown assets are not exactly the same. Because green assets are a larger component of the economy, they carry more systematic risk and, hence, have slightly lower market-to-book ratios than brown assets. Therefore, the green asset share is slightly below 73%.

challenges the conventional wisdom that the effectiveness of responsible investing policies should be measured by their impact on the cost of capital. Instead, we argue that the real impact of portfolio mandates is better assessed by examining the flow of capital induced by these mandates. This message is in line with recent research that documents the significant impact of bank lending choices on decarbonization efforts.[35]

Using a dynamic general equilibrium model calibrated to match key macroeconomic and asset pricing moments of the US economy, we show that portfolio mandates can lead to substantial shifts in capital allocation over the long term. In our baseline calibration, we estimate that realistic mandates can increase the share of green capital in the economy by about 4% over the long run. This number gives some hope that mandates could be a useful policy tool in the effort to transition to a greener economy. For example, as reported by Hong et al. (2020), the European Commission estimates that an increase in energy and infrastructure investments of about 0.8% of the European Union's GDP is needed to achieve a net-zero target by midcentury.

We also demonstrate the relative importance of trading in the primary and secondary markets in response to the imposition of mandates. While in the short run, mandates are satisfied by rebalancing financial portfolios in secondary markets, in the long run, they are satisfied by reallocating physical capital in primary markets. The relative importance of these two markets depends on capital adjustment costs and investors' risk attitudes, but the impact of mandates on the cost of capital across sectors remains negligible in both the short and long run.

In summary, our results indicate that responsible investment policies can have a meaningful impact on capital allocation, even if the immediate financial metrics, such as the cost of capital, show minimal changes. By focusing on the real allocation of capital rather than just financial metrics, policymakers and investors can better understand and assess the potential of responsible investing to drive economic and environmental change.

[35] For example, Green and Vallee (2024) find that bank exits from coal lead to a reduction of carbon-dioxide emissions by one gigaton between 2015 and 2021, equivalent to the lifetime emissions of twenty million gasoline-powered vehicles.

A. Proofs

Proof of Proposition 1

The intertemporal budget constraint in equation (7) can be written as

$$\tilde{c}_u = R_f(1 - w_u^\top \mathbf{1}) + w_u^\top \tilde{R} + \tilde{\pi}_u^\top \mathbf{1}, \tag{25}$$

with $w_u := [w_{G,u}, w_{B,u}]^\top$ the vector of portfolio weights in the G and B firms, $\tilde{R} := [\tilde{R}_G, \tilde{R}_B]^\top$ the vector of returns on capital, and $\tilde{\pi}_u := [\tilde{\pi}_{G,u}, \tilde{\pi}_{B,u}]^\top$ the vector of profits accruing to the unconstrained investor.

Each unconstrained investor is entitled to a fraction of the total profit $\tilde{\Pi}_j$ that is proportional to $\hat{w}_{j,u}/K_j$, the share of capital invested in sector j, that is,

$$\tilde{\pi}_{j,u} = \frac{\hat{w}_{j,u}}{K_j}\tilde{\Pi}_j, \quad j = G, B, \tag{26}$$

where, by equation (5), the total realized profit in sector j is $\tilde{\Pi}_j = (1-\alpha)\tilde{A}_j K_j^\alpha$, $j = G, B$. Because investors are atomistic, when choosing their optimal portfolio weights w_u in equation (8), they take the vector of returns $\tilde{R}$ and profits $\tilde{\pi}_u$ as given. From equation (4), the return on capital is $\tilde{R}_j = \alpha \tilde{A}_j K_j^{\alpha-1}$, and, therefore, we can write the profit $\tilde{\pi}_{j,u}$ as follows

$$\tilde{\pi}_{j,u} = \hat{w}_{j,u}\frac{1-\alpha}{\alpha}\tilde{R}_j, \quad j = G, B. \tag{27}$$

where the portfolio weights $\hat{w}_u := [\hat{w}_{G,u}, \hat{w}_{B,u}]^\top$ are taken as given in the optimization (8). Of course, in equilibrium, it must be that $\hat{w}_u$ equals the optimal portfolio w_u.

Under the above specification, we can rewrite the intertemporal budget constraint in equation (25) as

$$\tilde{c}_u = R_f(1 - w_u^\top \mathbf{1}) + \left(w_u + \frac{1-\alpha}{\alpha}\hat{w}_u\right)^\top \tilde{R}, \tag{28}$$

from which obtain the mean and variance of $\tilde{c}_u$,

$$\mathbb{E}[\tilde{c}_u] = R_f(1 - w_u^\top \mathbf{1}) + \left(w_u^\top + \frac{1-\alpha}{\alpha}\hat{w}_u^\top\right)\mathbb{E}[\tilde{R}], \quad \text{and} \tag{29}$$

$$\mathrm{Var}[\tilde{c}_u] = \left(w_u + \frac{1-\alpha}{\alpha}\hat{w}_u\right)^\top \Sigma_R \left(w_u + \frac{1-\alpha}{\alpha}\hat{w}_u\right), \tag{30}$$

with Σ_R denoting the covariance matrix of returns, i.e., $\mathrm{Cov}(\tilde{R}_j, \tilde{R}_\ell) = \alpha^2 \rho \sigma_{A_j}\sigma_{A_\ell} K_j^{\alpha-1} K_\ell^{\alpha-1}$, with $j, \ell \in \{G, B\}$.

Taking the first-order conditions with respect to w_u in equation (8), and using equations (29) and (30), we obtain

$$-R_f\mathbf{1} + \mathbb{E}[\tilde{R}] - \gamma_a\Sigma_R\left(w_u + \frac{1-\alpha}{\alpha}\hat{w}_u\right) = 0. \tag{31}$$

Imposing the equilibrium condition $\hat{w}_u = w_u$ we obtain that the optimal portfolio of the unconstrained investor is

$$w_u = \frac{\alpha}{\gamma_a}\Sigma_R^{-1}(\mathbb{E}[\tilde{R}] - R_f\mathbf{1}). \tag{32}$$

Using the definition of returns from equation (4) in the above expression we obtain the portfolio weights in equations (10)–(11). ∎

Online Appendix

OA.I. Details of Solving the Multiperiod Model

In this section of the Online Appendix, we explain how we solve the multiperiod model described in Section III of the manuscript. First, we explain how we detrend the model so that the resulting model is stationary. Then, we describe the numerical algorithm used to solve the stationary model.

OA.I.A. Detrending

The model is non-stationary because the aggregate component of TFP, A_t, grows at the rate g, that is, $A_t = A_0 G^t$, where $G := 1 + g$. Without loss of generality, we set $A_0 = 1$. However, it is possible to rewrite the model as a stationary model by detrending by the balanced growth path. Along the balanced growth path, the variables $Y_{j,t}$, $K_{j,t}$, $D_{j,t}$, $V_{j,t}$, $I_{j,t}$, $C_{i,t}$, $W_{i,t}$, w_t all vary around the trend $G^{\zeta t}$, with $\zeta := \frac{1-\theta}{1-\alpha\theta}$. Thus, we can define $\hat{X}_t = X_t G_t^{-t\zeta}$ the detrended value of any variable X_t and $A_t = A_0 G^t$, the detrended value of the TFP. To get ζ, we simply apply this detrending to the production function in equation (21) of the main text. This yields

$$\begin{aligned} \hat{Y}_{j,t}\, G^{\zeta t} &= \left(\hat{K}_{j,t} G^{\zeta t}\right)^{\alpha\theta} \left(G^t Z_{j,t} L_{j,t}\right)^{1-\theta} \\ &= \underbrace{\hat{K}_t^{\alpha\theta} \left(Z_{j,t} L_{j,t}\right)^{1-\theta}}_{=\hat{Y}_{j,t}} G^{[\zeta(\alpha\theta)+1-\theta]t}, \end{aligned} \tag{OA1}$$

and therefore, $\zeta := \frac{1-\theta}{1-\alpha\theta}$, and the detrended Cobb-Douglas production function is

$$\hat{Y}_{j,t} = \hat{K}_t^{\alpha\theta} \left(Z_{j,t} L_{j,t}\right)^{1-\theta}. \tag{OA2}$$

The variables $\tilde{M}_{i,t+1}$, $R_{j,t}$, $w_{j,i,t}$, and $L_{j,t}$ do not need to be detrended because they are stationary in the original model. We can then rewrite the model's key equations in terms of their stationary versions.

One can then guess and verify that $U_i(W_{i,t})$ also varies around the same trend. In fact, starting from the original recursive utility formulation, we have:

$$\mathcal{U}_i(W_{i,t}) = \max_{\{C_{i,t}, w_{G,i,t}, w_{B,i,t}\}} \left\{ (1-p\beta) C_{i,t}^{1-1/\psi} + p\beta \left(\mathbb{E}_t[\mathcal{U}_i(W_{u,t+1})^{1-\gamma}] \right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}},$$

or, equivalently,

$$\frac{\mathcal{U}_i(W_{i,t})}{(1-p\beta)^{\frac{1}{1-1/\psi}}} = \max_{\{C_{i,t}, w_{G,i,t}, w_{B,i,t}\}} \left\{ C_{i,t}^{1-1/\psi} + p\beta \left(\mathbb{E}_t \left[\left(\frac{\mathcal{U}_i(W_{i,t+1})}{(1-p\beta)^{\frac{1}{1-1/\psi}}} \right)^{1-\gamma} \right] \right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}}.$$

Denoting by $U_i(W_{i,t}) := \frac{\mathcal{U}_i(W_{i,t})}{(1-p\beta)^{\frac{1}{1-1/\psi}}}$ we have:

$$U_i(W_{i,t}) = \max_{\{C_{i,t}, w_{G,i,t}, w_{B,i,t}\}} \left\{ C_{i,t}^{1-1/\psi} + p\beta \left(\mathbb{E}_t[U_i(W_{i,t+1})^{1-\gamma}] \right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}},$$

which is equation (19) in the main text. Multiplying both sides by $G^{-\zeta t}$ and rearranging terms, we obtain

$$U_i(W_{i,t})G^{-\zeta t} = \max_{\{C_{i,t}, w_{G,i,t}, w_{B,i,t}\}} \left\{ \left(C_{i,t}G^{-\zeta t} \right)^{1-1/\psi} + p\beta \left(\mathbb{E}_t \left[\left(U_i(W_{i,t+1})G^{-\zeta t} \right)^{1-\gamma} \right] \right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}}$$

$$= \max_{\{C_{i,t}, w_{G,i,t}, w_{B,i,t}\}} \left\{ \left(C_{i,t}G^{-\zeta t} \right)^{1-1/\psi} + p\beta G^{\zeta(1-1/\psi)} \left(\mathbb{E}_t \left[\left(U_i(W_{i,t+1})G^{-\zeta(t+1)} \right)^{1-\gamma} \right] \right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}}.$$

Defining the detrended utility $\hat{U}_{i,t} := U_i(W_{i,t})G^{-\zeta t}$ and consumption $\hat{C}_{i,t} = C_{i,t}G^{-\zeta t}$, we have

$$\text{(OA3)} \qquad \hat{U}_{i,t} = \max_{\{\hat{C}_{i,t}, w_{G,i,t}, w_{B,i,t}\}} \left\{ \hat{C}_{i,t}^{1-1/\psi} + p\beta G^{\zeta(1-1/\psi)} \left(\mathbb{E}_t \left[\hat{U}_{i,t+1}^{1-\gamma} \right] \right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}}.$$

Each investor $i = u, c$ solves the problem in equation (OA3) subject to the detrended intertemporal budget constraint from equation (20) in the main text

$$\text{(OA4)} \quad \hat{W}_{i,t+1} = G^{-\zeta} \left(\hat{W}_{i,t} + \hat{\omega}_t L_{i,t} - \hat{C}_{i,t} \right) \left(R_{f,t} + w_{G,i,t}(R_{G,t+1} - R_{f,t}) + w_{B,i,t}(R_{B,t+1} - R_{f,t}) \right),$$

where the return is $R_{j,t+1} = \frac{G^{\zeta}\hat{V}_{j,t+1}}{\hat{V}_{j,t} - \hat{D}_{j,t}}$. Firms produce output $\hat{Y}_{j,t}$ according to the production function derived in equation (OA2).

The firm's value is the discounted value of its dividends,

$$\text{(OA5)} \qquad \hat{V}_{j,t}(\hat{K}_{j,t}) = \max_{L_{j,t}, \hat{I}_{j,t}} \hat{D}_{j,t}(k_{j,t}) + E_t \left[\tilde{M}_{u,t+1} G^{\zeta} \hat{V}_{j,t+1}(\hat{K}_{j,t+1}) \right],$$

where $\tilde{M}_{u,t+1}$ is the SDF of the unconstrained investors. The optimization in (OA5) is subject to the capital-accumulation equation, which, using $\delta > 0$ to denote capital depreciation, is

$$\text{(OA6)} \qquad \hat{K}_{j,t+1} = G^{-\zeta} \left((1-\delta)\hat{K}_{j,t} + \hat{I}_{j,t} \right).$$

Firm j's dividends are therefore given by

$$\text{(OA7)} \qquad \hat{D}_{j,t}(\hat{K}_{j,t}) = \underbrace{\hat{Y}_{j,t} - \hat{\omega}_t L_{j,t}}_{:=\hat{\Pi}_{j,t}} - \hat{I}_{j,t} - \eta \left(\frac{\hat{I}j,t}{\hat{K}_{j,t}} - \hat{\delta} \right)^2 \hat{K}_{j,t}, \quad \eta > 0,$$

where we set $\hat{\delta} = \delta + G^{\zeta} - 1 > 0$ so that adjustment costs are zero in the steady state. The quantity $\hat{\Pi}_{j,t} = (\hat{K}_{j,t})^{\alpha\theta}(Z_{j,t}L_{j,t})^{(1-\theta)} - \hat{\omega}_t L_{j,t}$ represents firm j's profit.

OA.I.B. Numerical Algorithm

In this section, we describe the algorithm to numerically solve the problem in Section III in the main text. The algorithm consists of four steps

1. *State space and initial beliefs.* We start by defining the state space, i.e., the set of state variables describing the problem and the investors' beliefs, i.e., the mapping between the state space and the relevant variables (e.g., wages, asset prices, etc.), that investors and firms need to solve their problems.

2. *Firm's optimal investment in partial equilibrium.* Given the set of beliefs from Step 1, we obtain each firm's optimal investment from the investment's Euler equation.

3. *Investors' optimal consumption and portfolio in partial equilibrium.* Given the set of beliefs from Step 1 we solve for each investor (constrained and unconstrained) using dynamic programming and value-function iteration.

4. *Belief updating.* Using the policy functions obtained from Steps 2 and 3, we simulate the model for one period from each point in the state space. We use the results of this "short simulation"to update the beliefs about the relevant variables. Given the updated beliefs we go back to Step 2 and continue until the beliefs have converged.

Once beliefs have converged, we simulate the model for many periods and use the results of this "long simulation" to compute the moments of interest. Below, we describe these steps in greater detail.

Step 1: State space and initial beliefs

The aggregate state space consists of four state variables: productivity states in the G and B sectors, $(Z_{G,t}, Z_{B,t})$, the quantity of aggregate capital $\hat{K}_t = \hat{K}_{G,t} + \hat{K}_{B,t}$, the share of green capital, $S_{G,t} = \hat{K}_{G,t}/\hat{K}_t$, and the wealth share of constrained investors, $S_{c,t} = \hat{W}_{c,t}/(\hat{W}_{c,t} + \hat{W}_{u,t})$. We define the aggregate state space as the vector $\Omega_t = (Z_{G,t}, Z_{B,t}, \hat{K}_t, S_{G,t}, S_{c,t})$. We assume that each of the two productivity states $Z_{j,t}$ follows a two-state Markov process and that the remaining three continuous variables take values on grids of sizes 11, 13, and 7, respectively. Thus, Ω_t can take $2 \times 2 \times 11 \times 13 \times 7 = 4,004$ values.[36] Each investor's state space consists of its wealth $\hat{W}_{i,t}$, which we discretize on a grid of size 37 and an indicator for whether the investor is constrained or not.

[36]We have experimented extensively with grid sizes and find that results are unaffected by finer grids.

We begin by initializing beliefs about all the relevant aggregate variables as a function of the state. Specifically, we initialize beliefs about the risk free rate $R^f(\Omega_t)$, firm values $\hat{V}_j(\Omega_t)$, investment $\hat{I}_j(\Omega_t)$, wage $\hat{\omega}(\Omega_t)$, and consumption $\hat{C}_i(\Omega_t)$. We also initialize beliefs about the evolution of the state variables as a function of the current state and of the realized shocks: $\hat{K}_{t+1}(\Omega_t, Z_{G,t+1}, Z_{B,t+1})$, $S_{G,t+1}(\Omega_t, Z_{G,t+1}, Z_{B,t+1})$, and $S_{c,t+1}(\Omega_t, Z_{G,t+1}, Z_{B,t+1})$. Defining the belief about $\hat{K}_{t+1} = G^{-\zeta}((1-\delta)\hat{K}_t + \hat{I}_{G,t} + \hat{I}_{B,t})$ and $S_{G,t+1} = \frac{G^{-\zeta}(1-\delta)\hat{K}_{G,t+1}}{\hat{K}_{t+1}}$ is immediate if one has beliefs about $\hat{I}_{j,t}$, and therefore the only additional belief is about the wealth share of the constrained investors, $S_{c,t+1}$.

Additionally, we define an auxiliary state space for asset price deviations from beliefs $\Omega_t^{aux} = (\Delta\hat{V}_{G,t}, \Delta\hat{V}_{B,t}, \Delta R_t^f)$ with size $5 \times 5 \times 5 = 125$, where $\Delta\hat{V}_{j,t} := \hat{V}_{j,t} - \hat{V}_j(\Omega_t)$ is the deviation of the price from the beliefs. The set Ω_t^{aux} is not an actual state space because in equilibrium, all prices and aggregate quantities are only functions of the aggregate state Ω_t. Hence, in equilibrium, once the model has converged, we have $\Omega_t^{aux} = (0,0,0)$. However, as we explain below in Step 4, the set Ω_t^{aux} is needed to ensure that beliefs can be updated before the model has reached an equilibrium.

Step 2: Firm's optimal investment in partial equilibrium

Given beliefs about the consumption of the unconstrained investors at t and the evolution of the state at $t+1$, we can compute beliefs about the realized SDF at $t+1$. For Epstein-Zin utility, the SDF is

$$M(\Omega_t, Z_{G,t+1}, Z_{B,t+1}) = \beta \left(\frac{G^{\zeta}\hat{C}_u(\Omega_{t+1})}{\hat{C}_u(\Omega_t)} \right)^{-\frac{1}{\psi}} \left(\frac{\hat{U}(\Omega_{t+1})}{\mathbb{E}_t\left[\hat{U}(\Omega_{t+1})^{1-\gamma}\right]^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi}-\gamma}.$$

Thus, to construct the beliefs about the realized SDF we need to solve the recursion in equation (OA3). This requires interpolating $\hat{C}_u(\Omega_{t+1})$ over the state at $t+1$ because the predicted values of Ω_{t+1} may not lie exactly at the grid-points.

Given the SDF, at each point in the aggregate state space Ω_t, each firm solves the problem defined in equation (OA5). From equation (OA2), the optimal labor $L_{j,t}$ that maximizes the firm's profit $\hat{\Pi}_{j,t}$ is $L_{j,t} = (1-\theta)^{\frac{1}{\theta}}\hat{K}_{j,t}^{\alpha} Z_{j,t}^{\frac{1-\theta}{\theta}} \hat{\omega}_t^{-\frac{1}{\theta}}$, so we can rewrite profits as

$$\hat{\Pi}_{j,t} = \theta(1-\theta)^{\frac{1-\theta}{\theta}} Z_{j,t}^{\frac{1-\theta}{\theta}} \hat{\omega}_t^{-\frac{1-\theta}{\theta}} \hat{K}_{j,t+1}^{\alpha}.$$

Using this expression for profits in equation (OA7) then the maximization in equation (OA5) is only over investment. Taking the first order condition with respect to $\hat{I}_t$, we have

$$\mathbb{E}_t\left[\tilde{M}_{u,t+1}\frac{\partial\hat{V}_{j,t+1}}{\partial\hat{K}_{j,t+1}}\right] = 1 + 2\eta\left(\frac{\hat{I}_{j,t}}{\hat{K}_{j,t}} - \hat{\delta}\right). \tag{OA8}$$

Using the envelope condition in the firm's maximization problem from equation (OA5), we have

$$\begin{aligned}\frac{\partial\hat{V}_{j,t}}{\partial\hat{K}j,t} &= \frac{\partial\hat{\Pi}_{j,t}}{\partial\hat{K}_{j,t}} + 2\eta\left(\frac{\hat{I}_{j,t}}{\hat{K}_{j,t}} - \hat{\delta}\right)\frac{\hat{I}_{j,t}}{\hat{K}_{j,t}} - \eta\left(\frac{\hat{I}_{j,t}}{\hat{K}_{j,t}} - \hat{\delta}\right)^2 + \mathbb{E}_t\left[\tilde{M}_{u,t+1}\frac{\partial\hat{V}_{j,t+1}}{\partial\hat{K}_{j,t+1}}\right](1-\delta) \\ &= \frac{\partial\hat{\Pi}_{j,t}}{\partial\hat{K}_{j,t}} + 1 - \delta + \eta\left(\frac{\hat{I}_{j,t}}{\hat{K}_{j,t}} - \hat{\delta}\right)^2 + 2\eta(1-\delta+\hat{\delta})\left(\frac{\hat{I}_{j,t}}{\hat{K}_{j,t}} - \hat{\delta}\right),\end{aligned} \tag{OA9}$$

where the second equality follows from the optimality condition (OA8) and with

$$\frac{\partial\hat{\Pi}_{j,t}}{\partial\hat{K}_{j,t}} := \alpha\theta(1-\theta)^{\frac{1-\theta}{\theta}} Z_{j,t}^{\frac{1-\theta}{\theta}} \hat{\omega}_t^{-\frac{1-\theta}{\theta}} \hat{K}_{j,t}^{\alpha-1}. \tag{OA10}$$

Using equation (OA9) in the first order condition (OA8), we arrive at the firm's Euler equation $E_t[\tilde{M}_{u,t+1}R^k_{j,t+1}] = 1$, where $R^k_{j,t+1}$ is the marginal return on capital,[37]

$$R^k_{j,t+1} = \frac{\frac{\partial\Pi_{j,t+1}}{\partial\hat{K}_{j,t+1}} + 1 - \delta + 2\eta(1-\delta+\hat{\delta})\left(\frac{\hat{I}_{j,t+1}}{\hat{K}_{j,t+1}} - \hat{\delta}\right) + \eta\left(\frac{\hat{I}_{j,t+1}}{\hat{K}_{j,t+1}} - \hat{\delta}\right)^2}{1 + 2\eta\left(\frac{\hat{I}_{j,t}}{\hat{K}_{j,t}} - \hat{\delta}\right)}. \tag{OA11}$$

To find investment such that $\mathbb{E}_t[\tilde{M}_{u,t+1}R^k_{j,t+1}] = 1$, we start with a guess for investment, compute $\mathbb{E}_t[\tilde{M}_{u,t+1}R^k_{j,t+1}] - 1$, and increase (decrease) investment if this quantity is positive (negative).

Step 3: Investors' optimal consumption and portfolio in partial equilibrium

Given beliefs about dividends at t, firm values at t, and the evolution of the state at $t+1$, we can compute beliefs about returns $R_j(\Omega_t, Z_{G,t+1}, Z_{B,t+1}) = \frac{G^{\varsigma}\hat{V}_j(\Omega_{t+1})}{\hat{V}_j(\Omega_t)-\hat{D}_j(\Omega_t)}$ as a function of the state at t and the realized state at $t+1$. This requires interpolating $\hat{V}_j(\Omega_{t+1})$ over the state at $t+1$ because the predicted values of Ω_{t+1} may not lie exactly at the grid-points.

Then, using beliefs about returns, the wage at t, and the evolution of the state, we solve the investor's problem using value-function iteration on equation (OA3). This is a standard and

[37] When return-to-scale is constant, $\alpha = 1$, then there is no difference between firm j's marginal return on capital, $R^k_{j,t+1}$, and the equity return $R_{j,t+1}$. However, in general, the two are not the same and the firm's optimal choice of investment satisfies the Euler equation with the marginal return on capital.

relatively fast computation, given modern computing power and parallel processing. This gives us policies as functions of the aggregate state for consumption $\hat{C}_i(\Omega_t)$ and portfolio choice $w_{j,i}(\Omega_t)$.

In addition, in the last iteration, we solve the model over the extended state space $\Omega_t \times \Omega_t^{aux}$. When $\Omega_t^{aux} = (0,0,0)$, this leads to identical policies as the original calculation. However, if, for example, $\Omega_t^{aux} = (\epsilon, 0, 0)$, we solve for a policy where everything is exactly as in the original calculation, but the current price of the green firm is bigger than the belief: $\hat{V}_{G,t} = \hat{V}_G(\Omega_t) + \epsilon$. This implies that the return on investing in green firms is smaller than the equilibrium belief, and the investor will invest less in green firms.

Step 4: Beliefs updating

Starting from every point on the aggregate state space $\Omega_t = (Z_{G,t}, Z_{B,t}, \hat{K}_t, S_{G,t}, S_{c,t})$, we simulate the model one period forward. This implies that the aggregate capital is $\hat{K}_t$ and the aggregate green capital is $\hat{K}_t S_{G,t}$. The wealth share of constrained investors $S_{c,t}$ is determined at the start of the period by assuming that all constrained investors are assigned exactly the same wealth.[38]

At this stage, there is one important complication. To solve for households' policies, we need to know the wealth of each household. However, to do that, we need to know aggregate wealth, which is the sum of the values of the green and brown firms ($\hat{V}_{G,t} + \hat{V}_{B,t}$), because the supply of shares is normalized to one and the aggregate supply of the risk-free asset is zero. While we have beliefs about $\hat{V}_{G,t}$, $\hat{V}_{B,t}$, and R_t^f as functions of the state Ω_t, if the model has not yet converged to equilibrium, then setting prices equal to these (off-equilibrium) beliefs would not allow us to update beliefs. Furthermore, setting prices equal to these beliefs may result in markets not clearing—for example, if the belief about the price of green firms is too low, then the demand for green shares will exceed supply.

This is the reason we introduced the auxiliary state Ω_t^{aux}. At each point in the state space Ω_t, we solve for the price $\hat{V}_{j,t} = \hat{V}_j(\Omega_t) + \Delta\hat{V}_{j,t}$ that clears markets. For example, if for a given $\hat{V}_G(\Omega_t)$ the demand for green firms is too high, we increase $\hat{V}_{G,t}$ by shifting higher on the grid for $\Delta\hat{V}_{G,t}$. Because we have solved the investor's problem for $\Omega_t \times \Omega_t^{aux}$, it presents no difficulty to solve

[38]Numerically, during this step, all constrained investors are assigned exactly the same wealth, and separately all unconstrained investors are assigned exactly the same wealth. In the "long" simulation, all investors of the same type will not necessarily own exactly the same wealth because newborns are born with the average wealth of all of the dead (constrained and unconstrained), and therefore, the wealth of a newborn unconstrained investor is not necessarily the same as a one-year-old unconstrained investor. As discussed in the main text, this mixing prevents either type from dominating the wealth distribution. However, this mixing is very slow, and therefore, in practice, the cross-sectional differences in wealth across investors of the same type are very small. Therefore, the mean wealth of each type is approximately a sufficient state variable. Krusell and Smith (1998) show that even in models with significantly larger cross-sectional variation in wealth, average wealth is approximately a sufficient state variable.

for policies at higher or lower prices than the belief. Market clearing is an iterative process because when the price $\hat{V}_{G,t}$ increases, so does aggregate wealth, which causes a change in the investors' policies. Clearing markets means finding the prices $(\hat{V}_{G,t}, \hat{V}_{B,t}, R_t^f)$ such that aggregate demand for shares of each type of firm is one, and the demand for bonds is zero.

Once we have cleared markets at a particular point on the state space, we use the market-clearing prices to update beliefs about the risk-free rate $R^f(\Omega_t)$ and firm values $\hat{V}_j(\Omega_t)$. We also use the equilibrium quantities in the one-period simulation to update the beliefs about investment $\hat{I}_j(\Omega_t)$, wage $\hat{\omega}(\Omega_t)$, and consumption $\hat{C}_i(\Omega_t)$, and the evolution of the state $\hat{K}_{t+1}(\Omega_t, Z_{G,t+1}, Z_{B,t+1})$, $S_{G,t+1}(\Omega_t, Z_{G,t+1}, Z_{B,t+1})$, and $S_{c,t+1}(\Omega_t, Z_{G,t+1}, Z_{B,t+1})$.

We update the beliefs slowly, putting a weight of 0.95 on old beliefs so that the model converges smoothly. With an updated set of beliefs, we go back to Step 2 and continue until convergence. Once the model has converged, Step 2 ensures that the firm's Euler equation is satisfied, and the maximization in Step 3 ensures that the investors' Euler equations are satisfied. We then simulate the model over many periods to compute the moments of interest. To confirm that the solution algorithm converged correctly, in the long simulation, we compute the Euler equation errors for the unconstrained investor, that is, $\text{Avg}[MR_j] - 1$. In the baseline model with $\gamma = 5$, these are 0.0000, -0.0001, and 0.0002 for the risk-free rate, green return, and brown return, respectively; in the model with $\gamma = 75$, these are 0.0000, 0.0003, and -0.0001. We also compute the pseudo-R^2 between the beliefs and simulated values of key quantities in the model. In the baseline model with $\gamma = 5$, these are 0.9998, 1.0000, 0.9999, 0.9998, and 0.9999 for the SDF, constrained investors' share of wealth, the value of the green firm, the value of the brown firm, and the risk-free rate, respectively; in the model with $\gamma = 75$, these are 0.9998, 1.0000, 0.9996, 0.9995, and 0.9989.[39]

[39] We do not report the R^2 for aggregate capital or G capital share because they are 1.0 by construction. This is because the investment function is determined optimally in Step 2 (conditional on the other beliefs), and investment in the simulation is set based on the investment in Step 2. We do not report the R^2 for consumption because what matters is the SDF belief, not consumption. However, the R^2 for consumption is even higher than that for the SDF.

OA.II. Comparing Our Model to Berk and van Binsbergen (2024)

In this section, we show how our model, for the case of $\alpha = 0$, maps to the model in Berk and van Binsbergen (2024). In particular, we verify that our approach is fully consistent with theirs. They start from the CAPM relation on returns to derive the value of capital in the two sectors. In contrast, we start from basic demand and supply and bypass the need to invoke the CAPM. Of course, the CAPM holds in our setting as well.

While our model (for the case of $\alpha = 0$) is the same as the model in Berk and van Binsbergen (2024), there is one difference in how the two models are implemented. Berk and van Binsbergen implement mandates as a "screen," i.e., constrained investors are not allowed to hold brown stocks but are free to choose their investment in green stocks and the risk-free asset. We, instead, implement mandates by constraining the investor to have a minimum investment in green stocks $\overline{w}_G$ and maximum investment in brown stocks $\overline{w}_B$; moreover, we choose these constraints so that $\overline{w}_G + \overline{w}_B = 1$, which means that in our equilibrium investors do not invest in the risk-free asset. This is mathematically convenient because the total investment in risky assets coincides with total wealth. As we show below, the effectiveness of mandates would be stronger if we were to implement our model using the Berk and van Binsbergen approach because, in response to the equilibrium effects resulting from the mandate, the unconstrained investor can invest in the risk-free asset instead of the B asset, leading to a smaller dilution in the effect of the mandate.

OA.II.A. The Model

We now solve the model in Berk and van Binsbergen (2024), but using the notation described in the main text of our paper. We summarize below the differences in notation between the two papers.

	Our notation	Berk and van Binsbergen
Green/Brown	G/B	E/D
Risk aversion parameter	γ_a	$2k$
Fraction of constrained investors	x	γ
Constrained investors' weight in B assets	$\overline{w}_B$	0

There is a mass x of constrained investors and $1 - x$ of unconstrained investors. There are two stocks, G and B, representing the market portfolio. The dividends of the two stocks are $\tilde{A}_G$ and $\tilde{A}_B$, and their values are K_G and K_B.[40] The sum $K_G + K_B$ represents the value of the market

[40]Because there are no frictions in this economy, the price of capital is 1 and so the values K_G and K_B can also be interpreted as the quantity of capital, although this interpretation is a bit misleading in a pure endowment economy where capital is not used.

portfolio. Without loss of generality we can always normalize the value of the market portfolio to 1, and so we set $K_G + K_B = 1$.

All investors are endowed with a share of the market portfolio. They trade at the beginning of the period ($t = 0$) and consume the liquidating dividend at the end of the period ($t = 1$). Because we are in the case of an endowment economy, $\alpha = 0$, the stock returns are[41]

$$\tilde{R}_G = \frac{\tilde{A}_G}{K_G} \quad \text{and} \quad \tilde{R}_B = \frac{\tilde{A}_B}{K_B}. \tag{OA12}$$

The unconstrained investors choose optimal how much to invest in the G and B risky assets and the risk-free asset. They solve the following problem:

$$\max_{w_{G,u}, w_{B,u}} \mathbb{E}[\tilde{c}_u] - \frac{\gamma_a}{2} \operatorname{Var}[\tilde{c}_u], \tag{OA13}$$

where

$$\tilde{c}_u = (1 - w_{G,u} - w_{B,u}) R_f + w_{G,u} \tilde{R}_G + w_{B,u} \tilde{R}_B. \tag{OA14}$$

The solution to the problem of unconstrained investors is

$$w_{G,u} = \frac{1}{\gamma_a (1 - \rho^2)} \left(\frac{\mathbb{E}[\tilde{R}_G] - R_f}{\sigma^2_{R_G}} - \rho \frac{\mathbb{E}[\tilde{R}_B] - R_f}{\sigma_{R_G} \sigma_{R_B}} \right) \tag{OA15}$$

$$w_{B,u} = \frac{1}{\gamma_a (1 - \rho^2)} \left(\frac{\mathbb{E}[\tilde{R}_B] - R_f}{\sigma^2_{R_B}} - \rho \frac{\mathbb{E}[\tilde{R}_G] - R_f}{\sigma_{R_G} \sigma_{R_B}} \right). \tag{OA16}$$

The constrained investors, on the other hand, are not allowed to invest in the B assets; i.e., $w_{B,c} = 0$. They can, however, choose how much of their wealth to invest in the G asset with the remaining wealth invested in the risk-free asset. As mentioned above, this is the only difference in how mandates are implemented in our model and in Berk and van Binsbergen (2024). Thus, the constrained investors solve the problem:

$$\max_{w_{G,c}} \mathbb{E}[\tilde{c}_c] - \frac{\gamma_a}{2} \operatorname{Var}[\tilde{c}_c], \tag{OA17}$$

where

$$\tilde{c}_c = (1 - w_{G,c}) R_f + w_{G,c} \tilde{R}_G. \tag{OA18}$$

The solution to the problem of the constrained investors is

$$w_{G,c} = \frac{1}{\gamma_a} \frac{\mathbb{E}[\tilde{R}_G] - R_f}{\sigma^2_{R_G}}. \tag{OA19}$$

[41] Note that these returns are *not* equal to the marginal product of capital, unlike the case for $\alpha > 0$, simply because there is no capital in this economy. It is true, however, that as $\alpha \to 0$, the portfolio weights in our model, obtained by assuming that returns are the marginal product of capital, $\tilde{R}_j = \alpha \tilde{A}_j K_j^{\alpha - 1}$, converge to the weights of an endowment economy, where returns are the "average product of capital," $\tilde{R}_j = \tilde{A}_j / K_j$ as defined as in equation (OA12).

OA.II.B. Equilibrium with Mandates

The equilibrium market-clearing conditions are

$$K_G = x w_{G,c} + (1-x) w_{G,u}, \tag{OA20}$$

$$K_B = (1-x) w_{B,u}, \quad \text{and} \tag{OA21}$$

$$0 = x(1-w_{G,c}) + (1-x)(1-w_{G,u}-w_{B,u}). \tag{OA22}$$

Notice that, using equations (OA27) and (OA28) the market clearing condition for the risk-free asset, equation (OA22) is equivalent to

$$K_G + K_B = 1. \tag{OA23}$$

Thus, the equilibrium consists of the triplet (K_G, K_B, R_f) that satisfies the following system of equations

$$K_G = x w_{G,c} + (1-x) w_{G,u}, \tag{OA24}$$

$$K_B = (1-x) w_{B,u}, \quad \text{and} \tag{OA25}$$

$$1 = K_G + K_B, \tag{OA26}$$

where $w_{j,u}$, $j = G, B$ are given in equations (OA15)–(OA16) and $w_{G,c}$ is given in equation (OA19).

Proposition OA.II.1. *The system of equations (OA24)–(OA26) defining the equilibrium has a unique solution (K_G, K_B, R_f) given by*

$$K_G = \frac{\overline{A}_G - \gamma_a \sigma^2 \Sigma_G}{R_f}, \tag{OA27}$$

$$K_B = \frac{\overline{A}_B - \gamma_a \sigma^2 \left(\Sigma_B + \Gamma\right)}{R_f}, \quad \textit{and} \tag{OA28}$$

$$R_f = \overline{A}_G + \overline{A}_B - \gamma_a \sigma^2 (1+\Gamma), \tag{OA29}$$

where $\overline{A}_j := \mathbb{E}[\tilde{A}_j]$, $\Sigma_j := \frac{\text{Cov}(\tilde{A}_j, \tilde{A}_G + \tilde{A}_B)}{\text{Var}[\tilde{A}_G + \tilde{A}_B]} = \frac{\sigma^2_{A_j} + \rho \sigma_{A_G} \sigma_{A_B}}{\sigma^2}$, $j = G, B$ are the cash-flow betas *of the two stocks, $\sigma^2 := \sigma^2_{A_G} + \sigma^2_{A_B} + 2\rho \sigma_{A_G} \sigma_{A_B}$ and*

$$\Gamma := \frac{x}{1-x}(1-\rho^2)\frac{\sigma^2_{A_B}}{\sigma^2}. \tag{OA30}$$

The expected returns on the G and B stocks are

$$\overline{R}_G = R_f + \beta^m_G \gamma_a \sigma^2, \quad \textit{and} \tag{OA31}$$

$$\overline{R}_B = R_f + \left(\beta^m_B + \frac{\Gamma}{K_B}\right) \gamma_a \sigma^2, \tag{OA32}$$

where $\beta^m_G := \frac{\Sigma_G}{K_G}$ and $\beta^m_B := \frac{\Sigma_B}{K_B}$ are the return betas *with respect to the market portfolio.*

Proof: Using the definition of portfolio weights in equations (OA15), (OA16), and (OA19), we can rewrite the system (OA24)–(OA26) as follows

$$K_G = x\,\frac{\mathbb{E}[\tilde{R}_G]-R_f}{\gamma_a\sigma^2_{R_G}} + (1-x)\,\frac{1}{\gamma_a(1-\rho^2)}\left(\frac{\mathbb{E}[\tilde{R}_G]-R_f}{\sigma^2_{R_G}} - \rho\frac{\mathbb{E}[\tilde{R}_B]-R_f}{\sigma_{R_G}\sigma_{R_B}}\right), \tag{OA33}$$

$$K_B = (1-x)\,\frac{1}{\gamma_a(1-\rho^2)}\left(\frac{\mathbb{E}[\tilde{R}_B]-R_f}{\sigma^2_{R_B}} - \rho\frac{\mathbb{E}[\tilde{R}_G]-R_f}{\sigma_{R_G}\sigma_{R_B}}\right), \quad \text{and} \tag{OA34}$$

$$1 = K_G + K_B. \tag{OA35}$$

Using the definition of returns in equation (OA12) and simplifying, equations (OA33) and (OA34) become

$$1 = x\,\frac{\overline{A}_G - K_G R_f}{\gamma_a\sigma^2_{A_G}} + (1-x)\,\frac{1}{\gamma_a(1-\rho^2)}\left(\frac{\overline{A}_G - K_G R_f}{\sigma^2_{A_G}} - \rho\frac{\overline{A}_B - K_B R_f}{\sigma_{A_G}\sigma_{A_B}}\right), \quad \text{and} \tag{OA36}$$

$$1 = (1-x)\,\frac{1}{\gamma_a(1-\rho^2)}\left(\frac{\overline{A}_B - K_B R_f}{\sigma^2_{A_B}} - \rho\frac{\overline{A}_G - K_G R_f}{\sigma_{A_G}\sigma_{A_B}}\right). \tag{OA37}$$

Rearranging and simplifying, we can rewrite the above system as follows

$$\gamma_a(1-\rho^2)\sigma^2_{A_G} = (1-x\rho^2)\left(\overline{A}_G - K_G R_f\right) - (1-x)\rho\frac{\sigma_{A_G}}{\sigma_{A_B}}\left(\overline{A}_B - K_B R_f\right), \quad \text{and} \tag{OA38}$$

$$\frac{\gamma_a(1-\rho^2)}{1-x}\sigma^2_{A_B} = \left(\overline{A}_B - K_B R_f\right) - \rho\frac{\sigma_{A_B}}{\sigma_{A_G}}\left(\overline{A}_G - K_G R_f\right), \tag{OA39}$$

which is a linear system in K_G and K_B, whose solution is

$$K_G = \frac{\overline{A}_G - \gamma_a\sigma^2\Sigma_G}{R_f}, \quad \text{and} \tag{OA40}$$

$$K_B = \frac{\overline{A}_B - \gamma_a\sigma^2\left(\Sigma_B + \Gamma\right)}{R_f}, \tag{OA41}$$

where we defined $\Sigma_G := \frac{\sigma^2_{A_G}+\rho\sigma_{A_G}\sigma_{A_B}}{\sigma^2}$, $\Sigma_B := \frac{\sigma^2_{A_B}+\rho\sigma_{A_G}\sigma_{A_B}}{\sigma^2}$, $\sigma^2 := \sigma^2_{A_G} + \sigma^2_{A_B} + 2\rho\sigma_{A_G}\sigma_{A_B}$, and $\Gamma := \frac{x}{1-x}(1-\rho^2)\frac{\sigma^2_{A_B}}{\sigma^2}$. Using equations (OA40) and (OA41) in the third equilibrium condition, equation (OA35), we obtain an expression for the equilibrium risk-free rate in terms of primitives,

$$R_f = \overline{A}_G + \overline{A}_B - \gamma_a\sigma^2(1+\Gamma). \tag{OA42}$$

To prove the expressions of the expected returns (OA31)–(OA32), we start from the definition of returns (OA12) and use the values for K_G and K_B in equations (OA27)–(OA28). For the case of G we have

$$\overline{R}_G - R_f = \frac{\overline{A}_G}{K_G} - R_f = \frac{\overline{A}_G R_f}{\overline{A}_G - \gamma_a\sigma^2\Sigma_G} - R_f$$

$$= R_f \left(\frac{\gamma_a \sigma^2 \Sigma_G}{\overline{A}_G - \gamma_a \sigma^2 \Sigma_G} \right) = \frac{\gamma_a \sigma^2 \Sigma_G}{\frac{\overline{A}_G - \gamma_a \sigma^2 \Sigma_G}{R_f}}$$

$$= \frac{\gamma_a \sigma^2 \Sigma_G}{K_G} = \gamma_a \sigma^2 \beta_G^m, \tag{OA43}$$

where $\beta_G^m := \frac{\Sigma_G}{K_G}$. Following similar steps, for the case of B, we obtain

$$\overline{R}_B - R_f = \frac{\gamma_a \sigma^2 \left(\Sigma_B + \Gamma\right)}{K_B} = \gamma_a \sigma^2 \left(\beta_B^m + \frac{\Gamma}{K_B} \right). \tag{OA44}$$

∎

Remark OA.II.1. *After the following notation change: $K_G \to V_E$, $K_B \to V_D$, $\overline{A}_G \to \overline{D}_E$, $\overline{A}_B \to \overline{D}_D$, $\sigma_{A_G} \to \sigma_E$, $\sigma_{A_B} \to \sigma_D$, $\Sigma_G \to \Sigma_E$, $\Sigma_B \to \Sigma_D$, $\gamma_a \to 2k$, and $x \to \gamma$, equations (OA27) and (OA28) are identical to the equations for V_E and V_D in Berk and van Binsbergen (2024), specifically, the un-numbered equations after equation (6) in the main text of their paper, or, equivalently, equations (28) and (30) in their Appendix A.*

Remark OA.II.2. *The expressions for K_G and K_B show that the risk premium for G stocks is $\gamma_a \sigma^2 \Sigma_G$ and that for B stocks is $\gamma_a \sigma^2 (\Sigma_B + \Gamma)$, where Σ_G and Σ_B are the cash-flow betas relative to the market portfolio with cash-flows $A_G + A_B$.*

Remark OA.II.3. *Note that, because $K_G + K_B = 1$, $\overline{A}_G + \overline{A}_B \equiv \frac{\overline{A}_G + \overline{A}_B}{K_G + K_B}$. Hence $\overline{R}_m = \overline{A}_G + \overline{A}_B$ is the average gross return on the market portfolio. The expression for $\overline{R}_m$ is equivalent to*

$$\overline{R}_m = R_f + \gamma_a \sigma^2 (1 + \Gamma). \tag{OA45}$$

The market risk premium is therefore $\gamma_a \sigma^2 (1 + \Gamma)$. When there is no mandate, $x = 0$, we have $\Gamma = 0$, and the market risk premium is $\gamma_a \sigma^2$.

OA.II.C. How Would Our Section II Change If We Used the Formulation in Berk and van Binsbergen (2024)?

The only difference is that, because in Berk and van Binsbergen (2024) the constrained investor can invest in the risk-free asset, the portfolio weights in the risky assets do not need to sum up to one. Therefore, to define the pass-through ratio, we need to normalize the portfolio weights by the total investment in risky assets. Specifically, in the Berk and van Binsbergen (2024) version of the model, we would need to define the general-equilibrium (GE) and partial-equilibrium (PE) impact of mandates as:

$$\text{GE impact} := \left[x \times \frac{w_{G,c}}{w_{G,c}} + (1 - x) \frac{w_{G,u}}{w_{G,u} + w_{B,u}} \right] - \frac{w_G^*}{w_G^* + w_B^*}, \tag{OA46}$$

$$\text{(OA47)} \qquad \text{PE impact} := \left[x \times \frac{w_{G,c}}{w_{G,c}} + (1-x)\frac{w_G^*}{w_G^* + w_B^*}\right] - \frac{w_G^*}{w_G^* + w_B^*} = x \times \left(1 - \frac{w_G^*}{w_G^* + w_B^*}\right),$$

with the effective mandate pass-through ratio given by

$$\text{(OA48)} \qquad \text{Effective mandate pass-through ratio} := \frac{\text{GE impact}}{\text{PE impact}},$$

where w_j^* denote the weights in an unconstrained economy and $\frac{w_G^*}{w_G^* + w_B^*}$ the corresponding tangency portfolio. Because the mandate forces constrained investors to hold zero of asset B, the intended impact in partial equilibrium in equation (OA47) is the difference between 100% in G and the tangency portfolio in the unconstrained economy. This difference is multiplied by x because, in partial equilibrium, it is assumed that the unconstrained investors do not re-optimize in response to the changes resulting from the mandate, and so continue to hold the same weights w_j^*.

Below, we reproduce in Figures OA.I and OA.II the results obtained under the Berk and van Binsbergen (2024) formulation of the two-date model. These figures correspond to Figures I–II reported in Section II.[42] Comparing the two sets of figures, we see that the results are very similar under the two formulations. If anything, the effect of mandates is larger if we were to adopt the same implementation of the mandate as in Berk and van Binsbergen. This can be seen by comparing Panel B of Figure OA.II to Panel B of Figure II: for both $\gamma_a = 2$ and $\gamma = 5$, the effective mandate pass-through ratio is higher under the Berk and van Binsbergen formulation than under our formulation.

[42] Berk and van Binsbergen (2024) do not report the values of $\overline{A}_G$ and $\overline{A}_B$, σ_{A_G} and σ_{A_B} that they use. They target a value of the G sector $K_G = 0.73$, risk premium $\gamma_a \sigma^2 = 6\%$, a risk-free rate $R_f - 1 = 2\%$, correlation $\rho = 0.93$, and a mass of constrained agents $x = 0.02$. These moments can be satisfied by several combinations of values for $\overline{A}_G$, $\overline{A}_B$, σ_{A_G}, and σ_{A_B}. However, note that while these parameters will match moments in an economy with $\alpha = 0$, as we vary $\alpha > 0$, we will no longer match the moments.

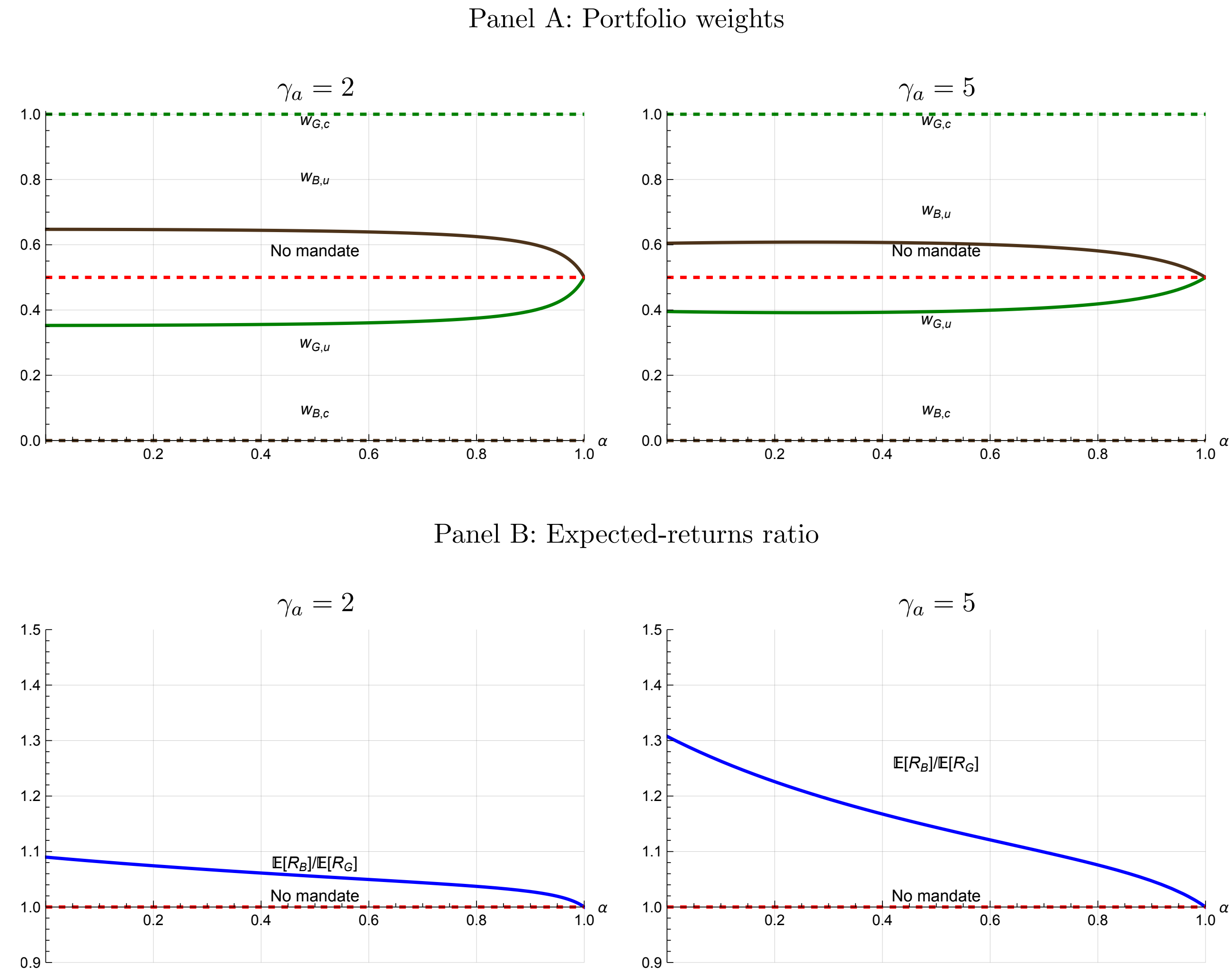

FIGURE OA.I

Equilibrium portfolio weights and expected returns

Panel A shows the equilibrium portfolio weights of the unconstrained and constrained investors that are allocated to the G and B sectors, *relative* to the total weight allocated to the$G$ and B sectors. Panel B shows the ratio between equilibrium expected returns, $\mathbb{E}[\tilde{R}_B]/\mathbb{E}[\tilde{R}_G]$. The dashed red line represents the weights and expected returns in the absence of a portfolio mandate. In the panels on the left, investors' risk aversion is $\gamma_a = 2$, and in the right panels $\gamma_a = 5$. The other parameter values are: $\mu_{A_G} = \mu_{A_B} = 1.05$, $\sigma_{A_G} = \sigma_{A_B} = 0.2$, $x = 50\%$, and $\overline{w}_B = 0$, with the constrained investors' holdings in the G and risk-free assets chosen optimally.

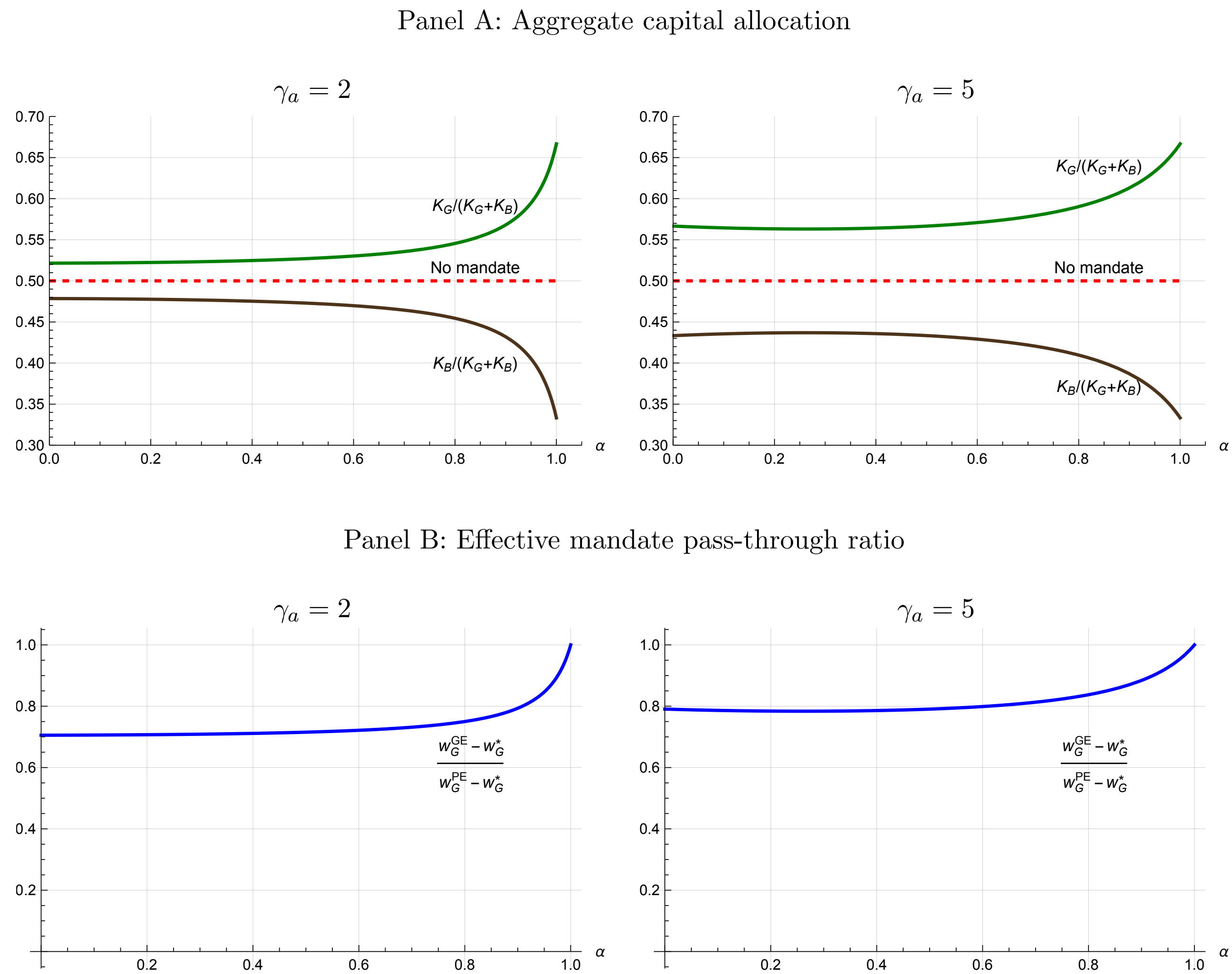

FIGURE OA.II

Capital allocation and effective mandate pass-through ratio

Panel A shows the equilibrium capital allocation across sectors G (green line) and B (brown line) as a function of the returns-to-scale parameter, α. The dashed red line is the capital allocation without a portfolio mandate. Panel B shows the effective mandate pass-through ratio in equilibrium, defined in equation (18). In the plots on the left, investors' risk aversion is $\gamma_a = 2$, and in the plots on the right, $\gamma_a = 5$. The other parameter values are: $\mu_{A_G} = \mu_{A_B} = 1.05$, $\sigma_{A_G} = \sigma_{A_B} = 0.2$, $x = 50\%$, and $\overline{w}_B = 0$, with the constrained investors' holdings in the G and risk-free assets chosen optimally.

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