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GREEN WITH ENVY:

IMPLICATIONS FOR CORPORATE INVESTMENT DISTORTIONS

by

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ABSTRACT

We model agents whose preferences exhibit envy. An envious agent's utility is increasing in what he has and decreasing in what others have. With this setup we are able to provide a new perspective on the nature of investment distortions with centralized and decentralized capital budgeting systems. Centralized capital budgeting leads to corporate socialism in investments in multidivisional firms, whereas decentralized capital budgeting leads to overinvestment. Numerous additional testable predictions are also generated.

GREEN WITH ENVY: IMPLICATIONS FOR CORPORATE INVESTMENT DISTORTIONS

"The impulse for envy is … inherent in the nature of man, and only its manifestation makes of it an abominable vice." Kant (1964, part II, § 36).

1. INTRODUCTION

To the layperson, the observation that human beings envy each other -- they are unhappy if someone else has more than they have -- would seem so obvious that it would need little elaboration. Those who have children observe it in siblings at a fairly early stage. While the behavioral manifestations of envy are more sophisticated in adults, its presence does not seem to diminish with age. Economics has recently begun to pay attention to envy, with several influential papers devoted to envy, "equity" and related "social preferences" (e.g., Bolton and Ockenfels (2000), Charness and Rabin (2002), and Fehr and Schmidt (1999)). But considerations of envy have largely been ignored in finance.[1] The purpose of this paper is to show that including envy in individual preferences may be worthwhile because it has the potential to shed new light on a variety of corporate investment distortions. The inclusion of envy in an individual's preferences means that the individual cares not only about his own absolute consumption but also about how his consumption compares with that of a reference group; he gains utility when his consumption exceeds his reference group's, and loses utility when his consumption falls below the reference group's. We use this specification to examine the different nature of investment distortions in centralized and decentralized capital budgeting systems.

Perhaps one reason why envy has not been studied much is that it seems irrational. Why should someone care about someone else's consumption? Moreover, it may also be that envy is believed not to cause any distortions. Banerjee (1990) points out, however, that envy can have

[1] Behavioral irrationality has been studied quite a bit to explain asset pricing anomalies (see Hirshleifer (2001) and Barberis and Thaler (forthcoming) for recent surveys), but it seems to us that its potential in corporate finance may be even greater. Whether many of these behavioral tendencies can be called irrationalities is questionable, however, since they have evolutionary foundations, as we study later, and can survive as dynamic equilibrium strategies. See for example, Wang (2001).

significant impact on economic outcomes. He makes a case for progressive taxation based on envy among individual taxpayers. Akerlof and Yellen (1990) hypothesize that workers care about their wages not in absolute terms but relative to what they consider to be "fair wages," where fair wages are related to "equity" considerations. Their framework generates involuntary unemployment. Similarly, Frank (1984) argues that what matters to workers is not just the wages they earn but also their status that is determined by their relative standing in the spectrum of wages. Thus, Frank dismisses the traditional notion that each worker must be paid his marginal product. Frank's main results are that differences in wages are less than differences in marginal products, and that such wage compression is greater when tasks require greater interaction among workers. He also empirically demonstrates wage compression among salespersons. Wage compression is also rationalized by Lazear (1989) who assumes that managers can expend effort to sabotage each other's work.[2]

Envy can be considered from four perspectives: biology, psychology, sociology and economics. The biological foundations of envy arise from the observation that all human preferences have an evolutionary basis, and attributes like envy are "hard-wired" into preferences because they maximize "reproductive success" (see Robson (2001b), for example)[3]. Dekel and Scotchmer (1999) present a winner-take-all game among males in which the prize is a female and hence reproductive success. In this setting, a concern for *relative* wealth arises among males[4].

[2] Other papers that explain wage compression include Levine (1991) who takes as given that cohesive work groups are more productive and wage dispersion reduces cohesiveness. Clark and Oswald (1996) find that satisfaction level of a worker depends on income relative to a 'comparison' or reference level.

[3] Robson (2001a) points out that there is a rich interaction between economics and biology. For example, it is well known that Charles Darwin was influenced by Thomas Malthus (1803). Malthus' thesis that the growth rate of a population would tend to exceed the growth rate of output implied, for Darwin, a struggle for existence that would lead to the survival of the fittest. Less recognized, however, is the impact of Adam Smith (1776), whose (selfish) utility/profit maximization hypothesis meant, for Darwin, that individuals would selfishly engage in a struggle for reproductive success.

[4] Cole, Mailath and Postleawaite (1992) present a model in which an agent's "status" is a ranking device that determines how well he fares in the marriage sector, a sector in which decisions are not made through markets. Since the marriage decision affects variables that affect an agent's utility, the agent's concern for status is derived endogenously and greater *relative* income means greater utility. A different approach is taken in Bisin and Verdier (1998) who show that an interest in status may arise in parents who want their children to share their utility functions. Suppose the population has two types of individuals, those who

The psychological foundations of envy can be found in Adams (1963), and its sociological implications are discussed in Elster (1991). Elster argues that if a person, when observing another person's consumption, can plausibly say to himself, "It could have been me", then the predisposition to envy is enhanced.[5]

A good introduction to the literature on envy in economics is provided by Mui (1995) who considers a setting in which an innovator introduces an innovation and the follower, who experiences envy, may retaliate at a personal cost. One of the main results is that the threat of the retaliation may deter innovation. Evidence on envy is provided by Martin (1981) who ran an experiment in which technicians at a factory were asked which pay level they would most like to know for comparison to their own wage. The choices were the lowest, average or highest pay levels of the technicians on the one hand and the lowest, average and highest pay levels of supervisors on the other. Most technicians wanted to know the highest pay among technicians. This experiment shows that an individual is most interested in comparing his own fortune to those closest to him.[6] Another interesting fact revealed by the experiment is that it is more important for a person to *not* be worse off than his peers than to be better off than them. This asymmetry plays a key role in the way we model envy.

There is a now burgeoning literature, both theoretical and experimental, on "social" or "interdependent" preferences.[7] This literature examines whether people care only about their own individual payoffs or about relative payoffs. Many of these papers take the view that people are motivated by considerations of fairness and thus wish to reduce inequity. That is, a person is unhappy if others outperform him and is also unhappy if he outperforms others. The growing body of experimental findings on "inequity aversion" has led to many papers that include this

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care about status and those who don't. Neither "pure state" is dynamically stable, but there may be a unique stable *mixture* over both types.

[5] See also Elster (1998) and Schoeck (1996).

[6] "We envy those who are near us in time, place, age, or reputation," Aristotle (*Rhetoric*, 1388a).

[7] Fehr and Schmidt (1999), Bolton and Ockenfels (2000), and Charness and Rabin (2002) are some recent articles.

aspect of behavior into individual preferences. For example, Fehr and Schmidt (1999) adopt a specification that captures the idea that individuals dislike inequity but their dislike for inequity is greater when they are worse off than when they are better off than others.

It is useful to compare our specification of envy to this literature. We assume individuals experience a decline in utility when their payoff is lower than that of others and experience an increase in utility when their payoff is higher than that of others. What our definition shares with the literature on inequity aversion is that people are unhappy if they are worse off than others. The difference is that the inequity-aversion literature assumes a symmetry in that individuals also dislike being better off than others. The experimental evidence on this is mixed. In some cases, individuals simply dislike any form of inequity, whereas in others they tend to behave selfishly, displaying an aversion only to being worse off than others. The behavior of individuals seems to depend on how they expect others to behave towards them. For example, Zizzo and Oswald (2001) provide experimental evidence that people may be willing to pay to reduce the incomes of even those who are worse off than them. Our specification of envy is consistent with this evidence. However, most of our results will follow with either equity-based (inequity-aversion) or envy-based preferences. What is important is that the component of utility that is based on relative payoff be a concave function of the relative payoff.[8] This feature is also consistent with the preferences in Fehr and Schmidt (1999) and is sufficient for all our results except those on overinvestment.

The research on envy has not included any work in finance. The closest literature is the use of "keeping up with the Joneses" and habit formation as features of preferences to explain the equity premium puzzle.[9] The "keeping up with the Joneses" feature of preferences refers to the idea that the utility of an individual depends on the individual's consumption relative to the

[8] See Clark and Oswald (1998) for a discussion of what they call "comparison-concave" utility functions.
[9] See Abel (1990), Chan and Kogan (2002), Constantinides (1990), and Gali (1994). For the equity premium puzzle, see Mehra and Prescott (1985).

aggregate past or present consumption of society.[10] However, neither envy as we model it nor the "keeping up with the Joneses" preference specification has been introduced to understand corporate finance phenomena.[11]

To examine the implications of envy for corporate finance, we model agents with utility functions increasing in their own wages and investment allocations and decreasing in the wages and investment allocations of others. We use this framework to provide simple envy-based explanations for the investment distortions observed in firms.

Investment distortions have been examined in the now emerging contemporary literature on capital budgeting (see Bernardo, Cai, and Luo (2001), Boot, Milbourn, and Thakor (forthcoming), Harris and Raviv (1996), Hirshleifer and Suh (1992), and Milbourn, Shockley, and Thakor (2001)). These papers have focused on informational frictions and explained how these could cause investment inefficiencies of different sorts and also influence the choice of centralized versus decentralized capital budgeting. We depart from that focus on informational asymmetries and analyze how the presence of envy alone causes investment distortions in centralized capital budgeting systems, even when information is symmetric. In particular, we observe socialism in investment choices. The introduction of private information by divisional managers could lead to decentralized capital budgeting, in which case there is overinvestment.

Corporate socialism with internal capital markets has been examined in the literature. Shin and Stulz (1998) use segment information from Compustat to measure investments in different segments of diversified firms. They find that the investment of each segment is more

[10] This feature differs from our notion of envy in many aspects. First, in our framework an individual envies people close to him rather than society as a whole. Second, in our framework envy produces externalities because an individual's actions affect the payoffs of those he envies; in the equity-premium-puzzle literature, an individual cannot significantly affect the payoff of the whole society. Third, the effect of envy is stronger when an individual is worse off than those he envies than when he is better off; by contrast the "keeping up with the Joneses" specification uses society's consumption as a numeraire regardless of the individual's payoff.

[11] The few papers exploring individual irrationality in corporate finance include de Meza and Southey (1996) and Manove and Padilla (1999), both of which consider implications of optimism among the entrepreneurs seeking credit from banks. We do not believe, however, that envy should be considered an irrationality of the sort included in behavioral biases like overconfidence and optimism.

sensitive to its own cash flow than the cash flows of other segments. More significantly, the sensitivity of the investment in a segment to the cash flows of other segments does not depend on whether its investment opportunities are better than those of the firm's other segments. This suggests that divisions are treated more alike than they really are, a form of "corporate socialism." Other papers that encounter similar results are Berger and Ofek (1995), Rajan, Servaes, and Zingales (2000) and Scharfstein (1998). Rajan, Servaes, and Zingales (2000) find that diversified firms transfer investments from high-q divisions to low-q divisions, and this sort of channeling of funds is increasing in the disparity of investment opportunities across the divisions. Moreover, these transfers are causally linked to the value loss in diversified firms. Scharfstein (1998) notes that divisional investments in diversified conglomerates are virtually insensitive to their investment opportunities.[12]

Our first main result is a simple explanation for such behavior. When agents envy each other, disparities in resource allocation cause agents' utilities to decline. To compensate, the owner/ principal is compelled to make wage adjustments that result in lower expected profits. In a centralized investment allocation system where the center determines the capital to be allocated to each division, corporate socialism in investment is a way to reduce envy-related organizational costs. This contrasts with Scharfstein and Stein's (2000) explanation for corporate socialism. In their model, there is a two-layered agency problem, one between the CEO and the shareholders, and the other between the CEO and the divisional managers. The divisional managers engage in selfish rent-seeking at the expense of firm value and this rent-seeking is greater by the manager of the weaker division. The CEO attempts to reduce such behavior by allocating more capital to the weaker division. The "bribe" to the weaker division's manager is paid via capital rather than cash because of the agency problem between the CEO and the shareholders involves the CEO wishing to conserve the cash flow for his own (wasteful) consumption. Rajan, Servaes, and Zingales

[12] However, the empirical observation that the conglomerate discount can be explained by corporate socialism has recently been challenged by Whited (2001) who shows that these findings result from measurement errors in q.

(2000) explain that divisions will invest inefficiently in "defensive" projects that better protect their surplus from being shared with other divisions, when divisional surpluses are very different. Corporate socialism seeks to minimize this by making the surpluses more alike. The common theme in these explanations is that there are agency problems due to a divergence of interests between shareholders and managers, and corporate socialism is the outcome. The fundamental difference between that and what we do is that our explanation holds even with symmetric information and even when moral hazard is not an issue, either because project choices are observable or because incentive contracts and/or equity ownership have more or less aligned managers' interests with shareholders'. Thus, for example, we predict corporate socialism even in owner-managed multidivisional firms, partnerships, cooperatives and the like.

Our second main result is that envy can lead to *overinvestment*. We show that when the center cannot dictate the allocation of capital to different divisions, say because of divisional private information, envy creates a natural propensity for managers to overinvest so as to hoard resources and deny them to others in the organization. We show that the overinvestment is worse when resources are in limited supply, because only with limited supply can overinvestment by one manager decrease the resources available to other managers. There is thus an element of "vindictiveness" that arises quite naturally with envy.

In addition to these main results, we provide a number of comparative statics results that both distinguish our theory from previous research and provide testable implications of our theory. First, we show that envy among managers in a conglomerate reduces firm value, and this decline in firm value gets larger as the variation in investment opportunities across divisions increases. Second, the expected decline in firm value is decreasing in the correlation between the investment opportunities of two divisions; in other words, the cost of envy is greater when divisions are more diverse in their investment opportunities. Third, the firm suffers a greater *fractional* reduction in firm value due to envy as the number of divisions in the firm increases. This suggests that if a firm is made up of ex ante identical divisions, the value of the firm will be

a concave function of the number of divisions. Also, the increase in the value of the firm due to the spinoff of a division will be greater if the number of divisions in the (pre-spinoff) firm is larger. Fourth, the average compensation of managers in a conglomerate will exceed the average compensation of similar managers in single-segment firms. Fifth, the cross-sectional variation in wages among managers in a conglomerate will be less than that across managers in separate single-segment firms, i.e., there is wage compression in conglomerates.

Envy affects outcomes in the applications we consider because the actions of an individual can impact the utilities of those he envies or those who envy him. When agents share resources, the allocation of resources to one agent affects the resources available to other agents. Further, the firm's resource allocation decisions take into account the effect of envy on the utilities of the agents. This contrasts with the "keeping up with the Joneses" approach in asset pricing where utilities are interdependent but that does not lead to strategic behavior because no individual can impact the resources allocated to other agents.

We view the principal contribution of our paper as twofold. First, we provide rather simple explanations for corporate socialism and overinvestment without requiring agents to engage in devious forms of moral hazard or invoking strong informational frictions. More importantly, what distinguishes envy from other settings in which relative payoffs matter, such as rank-order tournaments (see Lazear and Rosen (1981)), is that activities to influence agents' perceptions of their own (relative) social positions, while keeping their physical income possibilities the same, are important with envy.

Any paper that relaxes "standard" preference assumptions runs the risk of being criticized for introducing excessive modeling flexibility to explain the stylized facts. We have three points to make on this score. First, we believe envy is innate to human preferences, so it is in ignoring it that we are abstracting from reality. Second, choosing to model different objects of envy is in principle akin to modeling informational frictions or agency problems of different sorts; whether this is viewed as modeling flexibility or a serious consideration of the richness of human

interactions is a matter of taste. Third, we are able to use envy not only as a way to explain things, but also to generate new testable predictions.

The rest of the paper is organized as follows. Section 2 discusses the evidence on envy, provides a simple model to explain envy based on evolutionary biology, and specifies the utility function of envious agents. Section 3 studies corporate socialism and wage compression when capital allocation is centralized. Section 4 examines overinvestment when capital allocation is decentralized. Section 5 concludes with a discussion of testable predictions. All proofs are in the Appendix.

2. ENVY-BASED PREFERENCES

The purpose of this section is to provide a perspective on the preferences that arise with envy, and the foundations of these preferences. This motivates the way we model envy in later sections.

A. Specification of Envy: Who and What Do We Envy?

Envy presupposes a social comparison (Parrott (1991), Ben-Ze'ev (1992)), but not necessarily competition. *Envious agents want to be better more than they want to be better off*. This is consistent with experimental studies by Lehmann (2001) in which individuals reported satisfaction with the results of a sales competition between two stores in the same market for various combinations of sales in the current and previous periods. The subjects were more satisfied when the sales were equal but low for both the stores than when their own sales were higher but the sales of the competitor were even greater.

These studies raise an important reference question: who do we envy? The literature shows that *not* all social comparisons lead to envy. Envy is directed at those who are like us or equal to us but who turn out to be slightly superior to us (Parrott (1991)). Most people do not envy the Rockefellers' wealth because the discrepancy between that and their own wealth does not necessarily reflect badly on them. Silver and Sabini (1978) find that envy results only when the discrepancy between someone else's success and one's own failure serves to demonstrate

one's shortcomings. *Envy is greater when proximity is greater and when one can imagine, "I could be in his place"* (Elster (1991), Heider (1958), Parrott (1991)). A woman may envy another woman for her beauty, but she will probably not envy a handsome man. Ben-Ze'ev (1992) defines three components of emotional proximity as: (a) similarity in background, e.g., education, age, time, place, and opportunities; (b) closeness in current positions, e.g., status, salary, or possession of a certain object; and (c) relevance for self-evaluation. Bos and Tillmann (1985) use the term "neighborhood envy" to refer to the phenomenon of each person in a hierarchy primarily envying the person immediately above him. Envy is experienced when the targets of envy are *a priori* similar but turn out to be *ex post* superior to the subject of envy. Thus, envy appears to evolve as a two-step process, the first step being the formation of a reference group consisting of those who are close to us and similar to us, and the second step being the realization of envy when those in the reference group do better than us.

The next relevant question is: what do we envy? People are envied both for what they are and what they have (Elster (1991)). Thus, we may envy another person's success, happiness, intelligence, health, good looks, material possessions, power, title, job, or status. However, envy is more likely to be felt when comparisons are made in domains that are especially relevant for how we define ourselves.[13] Salovey and Rodin (1984) conducted a laboratory study in which undergraduates received either positive or negative feedback about an area of study that was either central to their career choice or less relevant to their career choice. After this, they anticipated interacting with another student about whom they were provided positive or negative feedback in an area of study. The results showed that the symptoms of envy occurred only when students received negative feedback about the area of study that was central to their career choice and then faced interaction with a student who excelled in the same domain.

[13] William James mentions in his classic textbook, *The Principles of Psychology*, that he was not bothered by the scholarly prowess of professors of Greek. It was only the brilliance of his colleagues in psychology that made him feel bad about himself. (See Salovey and Rothman (1991)).

Although envy may represent multiple emotions (Parrott (1991)), it is universally acknowledged that envy is inherently unpleasant. We shall interpret this to mean that envy reduces utility. Further, the intensity of envy and the accompanying loss of utility increase as the superiority of the target(s) of envy increases. We shall also assume that people form rational beliefs about future utility by anticipating the impact of future envy on their utility.

B. An Evolutionary Biology Model for Envy-based Preferences

One of the issues in any analysis of envy is that of the dimensions along which we envy others. In what follows, we show that an envious agent's utility typically has multiple arguments. One argument is the agent's own consumption, which would enter the utility function even in the absence of envy. However, there may also be other arguments that produce no direct consumption utility for the agent, but matter solely due to envy. An example is the resources controlled by the agent. The importance of this may be due to preferences that have been evolutionarily hard-wired to ensure reproductive success. This idea is finalized below.

Consider two males, indexed 1 and 2, who live for a period and consume C_1 and C_2, respectively at the end of the period. There is a female who mates with one of these males at the end of the period. The male that mates with the female achieves reproductive success, and evolution has programmed males to value this success at P units of consumption.[14] It is the female who decides which male to mate with. The decision of the female is based on her beliefs about the survival of the offspring. She bases her beliefs on the consumption C_1, C_2 of the males and also the resources controlled R_1, R_2 by the males. Greater consumption can be thought of as enhancing the physical appearance of a male and is likely to lead to healthier offspring. The resources controlled by a male are a signal of the ability of the male to gather resources. This ability to gather resources guarantees consumption for the future and hence affects the survival probabilities of the offspring. For example, male lions defend territories under their control and

[14] Following usual evolutionary arguments, there may have been males who did not value reproductive success but only those species have survived in which males value reproductive success.

prevent other male lions from entering these territories. The size of the territory owned by a male lion is an indicator of the power or status of that lion. The ability to gather resources is genetic to some extent and when passed on to offspring increases the chances of their survival; this augments the direct effect of resource-gathering on the consumption possibilities offered to young offspring and hence their early survival.

The notion that the resources controlled by a male, including territorial domain, do matter for reproductive success has been widely documented. Ardrey (1976) gives the anthropologist's viewpoint that we evolved as hunter-gatherers, so territorial/resource considerations were paramount in our evolution.[15] Gould and Gould (1989) survey mating practices and mate-selection strategies in various species and state, "In animals, territorial defense is a component of reproductive success that has resulted from sexual selection. It is hard not to suspect that the strong sense of property, of social and ethnic group, and even the senseless team loyalty that pervades the American genetic melting pot are visible expressions of innate compulsion to maximize hunter-gatherer fitness." Buss (1994), based on studies of mate-selection strategies in over 10,000 people, describes why men and women look for different attributes in their mates. He reports that women look for attributes in males that are most valuable in evolutionary adaptation, with the man's resources being one of the most heavily weighted criteria. He states "Wherever female show a mating preference, the male's resources are often the key criterion … But women needed cues to signal a man's possession of those resources. These cues may be indirect, such as personality characteristics … Economic resources, however, provide the most direct cue."

Based on this, we assume that the probability that the female will mate with male j is increasing in C_j and R_j. We model this in a simple way by assuming that with probability $0 < \gamma < 1$, the female mates with the male who has greater consumption, and with probability $1 - \gamma$ she mates with the male who has greater resources.

[15] Ardrey (1976) states, "We defend our space, our home, our village, our nation not because we choose but because we must."

The males can exert effort to increase their consumption and to acquire resources. Consumption can be high (C^H) or low (C^L) and resources can be high (R^H) or low (R^L). If a male exerts effort e on consumption, the probability that his consumption will be high is $p(e)$. Similarly, if a male exerts effort e in acquiring resources, the probability that his resources will be high is $q(e)$. The functions p and q have range [0, 1], are increasing and concave in e, and satisfy Inada conditions, $p'(0) = q'(0) = \infty$ and $p'(1) = q'(1) = 0$. Thus, there are decreasing returns to scale in pursuing either activity. The sum of the effort spent by any male is limited to the total effort that the male can exert, which is normalized to one unit.

The objective of each male then is to maximize the utility from consumption and the utility assigned to reproductive success. Thus, male 1 maximizes

$$E\left[u(C_1) + P\gamma\delta(C_1 - C_2) + P(1-\gamma)\delta(R_1 - R_2)\right] \tag{1}$$

where the function $\delta(x)$ is 0 for $x < 0$, 1 for $x > 0$, and $\delta(0) = 0.5$. Hence, each agent derives utility not only from absolute consumption but also from relative consumption and relative resources. Substituting the expressions for consumption and resources, each male will spend effort e on consumption to maximize

$$\begin{aligned} &p(e)u(C^H) + \{1-p(e)\}u(C^L) + P\gamma\left[p(e)\{1-p(e^*)\} + 0.5\,p(e)p(e^*) + 0.5\{1-p(e)\}\{1-p(e^*)\}\right] \\ &+ P(1-\gamma)\left[q(1-e)\{1-q(1-e^*)\} + 0.5q(1-e)q(1-e^*) + 0.5\{1-q(1-e)\}\{1-q(1-e^*)\}\right] \end{aligned} \tag{2}$$

where e^* is his belief about the effort spent by the other male on consumption. If each male cared only about his own consumption (that is, $P = 0$), he would choose $e^* = 1$. However, when males are concerned with reproductive success also ($P > 0$), they spread their effort out over increasing consumption and gathering resources. The effort allocation is determined by the first-order condition

$$p'(e^*)\{u(C^H) - u(C^L)\} + .5P\{\gamma p'(e^*) - (1-\gamma)q'(1-e^*)\} = 0 \tag{3}$$

There is an interior solution to the above equation because of the Inada conditions. Thus, *even though there is no direct utility from acquiring resources, agents care about relative*

resources because of the effect on reproductive success, a preference for which is evolutionarily hard-wired.

C. Specification of Envy-based Preferences

Since we are interested in studying the effect of envy in firms, we shall confine our analysis to envy arising from comparison of monetary and non-monetary benefits to employees in firms. Monetary benefits like wages, bonus, and stock options are examples of explicit incentives provided to employees. We shall refer to the monetary benefits as wages. In addition, employees may derive some non-monetary benefits like the satisfaction they derive from a large well-decorated office, the number of employees that supervise, the size of the budget they control, or the perks they enjoy (see Jensen and Meckling (1976)). The non-monetary benefits can be measured by the size of resources controlled by the individual. For the CEO of the firm this is interpreted as the size of the firm, and for a divisional manager this is the size of the division or the investment in the division. The wages and the resources controlled are natural candidates for envy because these are important proxies of the relative performances of different employees, and they correspond to consumption and resource-gathering in the previous section.

The utility of agent *i* is defined as

$$U_i = u(W_i) + \sum_j \rho_{ij}^W \phi(W_i, W_j) + \sum_j \rho_{ij}^I \psi(I_i, I_j) \tag{4}$$

where W_i and I_i are the wages of and resources (or investment) controlled by agent *i*, W_j and I_j are the corresponding quantities for agent *j*, ρ_{ij}^W is the propensity of agent *i* to envy agent *j* with respect to wages and ρ_{ij}^I is the propensity of agent *i* to envy agent *j* with respect to resources controlled. The function *u* represents envy-free utility, i.e., the utility that agent *i* will have when he does not envy anyone. We make the standard assumption that *u* is increasing and weakly concave in wages. The summation of the envy functions is over all agents *k* about whose payoffs information is naturally available to agent *i*. We envy those about whom we have information, who are in our proximity and similar to us; we cannot envy those about whom we don't have

information. Further, we typically do not make a deliberate attempt to acquire information about distant and dissimilar people in order to envy them. The functions ϕ and ψ measure the intensity of envy as a function of wage comparison and resource comparison, respectively. Each of these functions is increasing in its first argument and decreasing in its second argument. Further, both functions are concave. This is consistent with the notion that the negative effect of envy on a person when he is worse off than others is stronger than the positive effect when the person is better off than others by the same amount (see Banerjee (1990), Loewenstein, Thompson, and Bazerman (1989), Mui (1995), and Schoeck (1996)). Also notice that envy is based on separate comparisons of wages and resources. Since not being worse than others is more important than being better off than others, if one agent earns greater wages while the other gathers greater resources, envy may decrease the utilities of both agents because each suffers a decline in utility -- from the good the other agent has more of -- that exceeds the increase in utility from the good he has more of.

Our basic model, which we use for much of our analysis, consists of a firm with two divisions: division 1 and division 2. The firm has a single owner and two managers. The single owner may represent multiple shareholders of the firm, all of whom have a common objective. Division *j* is managed by manager *j*. Each manager is paid a wage and controls some resources. The managers are ex ante identical with risk-averse preferences. The managers envy each other equally but do not envy anyone else. With two managers, general utility function (4) specializes to:

$$U_i = u(W_i) + \phi(W_i - W_j) + \psi(I_i - I_j) \tag{5}$$

The function u is increasing and either concave, reflecting risk-aversion, or linear, reflecting risk-neutrality. The envy functions ϕ and ψ are defined on relative wages and relative

capital with $\phi(0)=\psi(0)=0$, $\phi'>0$, $\psi'>0$, $\phi''<0$, and $\psi''<0$ [16]. Each manager derives a direct utility from wages. In addition, each manager envies the wages and capital allocation of the other manager. Thus, capital enters the utility function only due to envy. Envy over wages increases the utility of the manager with greater wages and reduces the utility of the other manager. Similarly, envy over capital reduces (increases) the utility of the manager whose division obtains smaller (greater) capital allocation. Each manager's reservation utility is U^0. The owner of the firm is risk neutral in profits, net of managers' wages.

Our specification of envy presumes that each manager can observe the other's wages and capital investment. This is obviously realistic in public institutions like state universities and government departments, where salary information is in the public domain. However, in other organizations, pay secrecy is commonly practiced. In such cases, our specification is meant to capture the idea that the managers we consider are senior executives. Information about the compensation packages of senior executives in publicly-traded U.S. firms is widely disseminated. Even when executive salary is not disclosed, it seems reasonable that senior executives can noisily infer the compensation of their colleagues in the same firm from their lifestyles, resources controlled by those colleagues, and observable perquisites. Our results will be qualitatively sustained even if managers receive noisy (but informative) signals about each other's wages.

3. CORPORATE SOCIALISM IN CENTRALIZED CAPITAL BUDGETING

Consider a firm with division 1 and division 2 managed respectively by manager 1 and manager 2. The owner of the firm raises capital I which is then shared by the two divisions. The production function of division $j, j \in \{1, 2\}$, is given by

$$y_j = g(\theta_j) f(I_j) + \varepsilon_j, \tag{6}$$

[16] All the results in Section 3 will follow even if we relax the assumptions $\psi'>0, \phi'>0$ to consider a specification that embeds preferences based on equity-theory. These assumptions are required for the overinvestment results in Section 4.

where y_j is the output of division j, I_j is the capital invested in division j, θ_j is the productivity of division j, the function g is positive and increasing, the function f is positive, increasing, and concave, and the random terms ε_1 and ε_2 are independent and identically distributed. The productivities of the two divisions are drawn from a bivariate normal distribution with correlation ρ, and are independent of the random terms ε_1 and ε_2. The marginal distribution of θ_1 or θ_2 is normal with mean 0 and standard deviation σ.

There are three dates: 0, 1, and 2. At date 0, the owner and each manager enter into a contract specifying the wage and investment policy. At date 1, the productivities of the two divisions are observed and capital is allocated to the divisions and finally, at date 3, the outputs of the divisions are realized and the managers are paid their wages. The managers are essential for the operation of their divisions and must obtain their reservation utility of U^0 in order to continue in the firm.

We first discuss how capital is allocated in a centralized system in which the owner of the firm can observe and control the capital allocated to the two divisions. Let Θ denote the realization of productivities θ_1 and θ_2 of the two divisions. Because of symmetric information about Θ, wages and the investment are conditioned on Θ. The contract between the owner and the managers specifies the wages W_1 and W_2 and capital allocation I_1 and I_2 such that $I_1 + I_2 \leq I$, the total capital available. We first analyze the benchmark case in which managers do not envy each other so each manager's utility depends only on his own wage. The utility of manager j is

$$U_j = u\left(W_j\right) \tag{7}$$

where the function u is increasing and concave. The owner wants to maximize the value of the firm net of the wages paid to the managers. Since there is no moral hazard problem, there is no need to provide any incentives to the managers. The owner minimizes the expected wages paid by making the wages of the risk-averse managers independent of divisional outputs. The value of the firm is given by

$$V = E\left[g(\theta_1)f(I_1(\Theta)) + g(\theta_2)f(I_2(\Theta)) - I_1(\Theta) - I_2(\Theta) - W_1(\Theta) - W_2(\Theta)\right]. \tag{8}$$

The owner maximizes firm value by choosing capital allocation $\left(I_1^*(\Theta), I_2^*(\Theta)\right)$ such that

$$\begin{aligned} &I_1^*(\Theta) + I_2^*(\Theta) = I, \quad g(\theta_1)f'\left(I_1^*(\Theta)\right) = g(\theta_2)f'\left(I_2^*(\Theta)\right) \geq 1, \quad \text{or} \\ &I_1^*(\Theta) + I_2^*(\Theta) < I, \quad g(\theta_1)f'\left(I_1^*(\Theta)\right) = g(\theta_2)f'\left(I_2^*(\Theta)\right) = 1, \end{aligned} \tag{9}$$

and each manager's reservation utility is exactly met with a fixed wage:

$$W_j^*(\Theta) = u^{-1}\left(U^0\right). \tag{10}$$

We now examine how envy among managers affects capital allocation. Suppose the utility function of manager *i* is given by (5). Observe that each manager's utility depends not only on his own wages and (his division's) capital allocation, but also on the wages and capital allocation of the other manager.

The owner's problem now is to choose wages and capital allocation to maximize firm value in (8) subject to the total capital availability *I* and the following participation constraints of the two managers:

$$u\left(W_1(\Theta)\right) + \phi\left(W_1(\Theta) - W_2(\Theta)\right) + \psi\left(I_1(\Theta) - I_2(\Theta)\right) \quad \geq \quad U^0 \text{ and} \tag{11}$$

$$u\left(W_2(\Theta)\right) + \phi\left(W_2(\Theta) - W_1(\Theta)\right) + \psi\left(I_2(\Theta) - I_1(\Theta)\right) \quad \geq \quad U^0. \tag{12}$$

Proposition 1: *If managers envy each other, the investment levels in different divisions vary less than they would in the absence of envy. Envy leads to a reduction in firm value, and the reduction in firm value increases with the difference in the productivities of the two divisions.*

Proposition 1 shows that envy leads to a reduction in the difference in investment levels across divisions. Investment opportunities vary across divisions, so the value-maximizing (first-best) investments vary across divisions. However, when the managers obtain private benefits from investments in their divisions and envy each other's benefits, any cross-sectional variation in investment causes a net reduction in the utility of the manager receiving the lower investment, and this reduction is greater than the envy-induced increase in the utility of the manager receiving

the higher investment. The owner has to compensate for this utility reduction by providing a higher wage to the manager with the lower investment, which leads to a higher total wage bill. Thus, dispersion of investment across divisions creates a cost arising from envy. The firm's owner trades off this cost of higher total wages against the inefficiency of reducing cross-sectional divisional investment dispersion. It is this tradeoff that leads to corporate socialism, wherein some investment inefficiency is tolerated in the interest of lowering the total wage bill.

Proposition 2: *Envy leads to a reduction in firm value, and this reduction is decreasing in the correlation between the productivities of the two divisions.*

Proposition 1 showed that the owner trades off the cost of higher wages due to envy against the cost of inefficient investment through corporate socialism. Proposition 2 shows that envy leads to a reduction in firm value, partly due to the increased wages of managers and partly due to inefficient investment. As the correlation between divisions increases, the first-best investment dispersion across divisions diminishes, which reduces the effect of envy. Hence, an increase in the correlation between the investment productivities of divisions leads to a smaller decline in firm value due to envy. This is a novel testable prediction of our theory.

Proposition 3: *The absolute as well as fractional reduction in firm value due to envy is increasing in the number of divisions.*

Proposition 3 considers a general setting in which a firm has multiple divisions and the manager of each division envies the manager of every other division. The proposition shows that as the number of divisions increases, envy becomes a greater problem. The reduction in firm value due to envy is larger for firms with more divisions. This is partly due to the fact that firms with more divisions typically operate on a larger scale. However, the proposition shows that a reduction in firm value will obtain even without this effect because the *fractional* reduction in firm value due to envy is greater when the number of divisions is larger. The reason is that as the number of divisions increase, each manager envies more managers and the resulting reduction in

his expected utility is greater.[17] This prediction is consistent with the evidence reported by Berger and Ofek (1995).

Thus, reducing the number of divisions in a firm can reduce the cost of envy and increase firm value. Proposition 3 immediately implies the following corollary:

Corollary 1: *The spinoff of a division increases firm value. This increase in firm value in absolute as well as relative terms is increasing in the number of divisions.*

This result suggests that spinning off a division from a conglomerate may increase value when the managers in the conglomerate are envious of each other. Interestingly, the increase in firm value due to a spinoff depends on the number of divisions in the original conglomerate. The spinoff creates greater value when the number of divisions in the original conglomerate is larger. This is an easily testable prediction; we are not aware of any existing empirical evidence on this prediction. Now we discuss the effect of envy on the compensation received by the divisional managers.

Proposition 4: *The expected compensation of managers in a conglomerate exceeds the expected compensation of managers in the corresponding portfolio of single-segment firms.*

The intuition for Proposition 4 is as follows. The manager in a single-segment firm derives his utility from his compensation only and there is no cost of envy. However, in conglomerates, different managers envy each other. This envy reduces their expected utility because the investment levels in different divisions vary in response to the differences in the productivities of these divisions. The owner compensates the managers for this loss of utility due to envy by providing them greater wages than their counterparts get in single-segment firms.

We are not aware of any existing empirical evidence on wage levels in conglomerates relative to those in single-segment firms. However, there is extensive evidence in labor economics that wage levels are positively correlated with firm size. Further, even after controlling

[17] This is because the decrease in expected utility when the new managers get higher capital more than offsets the increase in expected utility when the new managers get lower capital.

for firm size and the skill levels of workers, wages tend to be higher in bigger plants than in smaller plants while job satisfaction tends to be lower in bigger plants than in smaller plants[18]. This evidence seems consistent with our intuition that workers in bigger plants can compare their wages with more workers and are thus likely to experience lower job satisfaction due to envy. They may need higher wages to compensate for this utility reduction, but wages may not fully compensate for the envy-related utility loss.

We have shown that managers in conglomerates get greater average compensation than in single-segment firms. It is interesting to see how envy affects the cross-sectional variation in wages. In order to analyze this, we now relax the assumption that the managers are ex ante identical and consider managers with different reservation utilities. These reservation utilities could be outcomes of labor demand and supply conditions, and variations in these across industries could result in cross-sectional variation in wages.

Proposition 5: *The cross-sectional variation in utility derived from wages is smaller across managers in a conglomerate than across managers in the corresponding portfolio of single-segment firms. The cross-sectional variation in wages too is smaller across managers in a conglomerate than across managers in the corresponding portfolio of single-segment firms if any one of the following conditions is satisfied:*

(i) The managers are risk-neutral.

(ii) *The managers exhibit envy in wages but not in capital investment.*

(iii) *Investment opportunities are identical across divisions.*

The intuition for Proposition 5 is as follows. When reservation utilities vary across managers in single-segment firms, their wages adjust to account for this; managers with higher reservation utilities receive greater wages, so that the reservation utility of each manager is exactly satisfied. The only cost to the owner of providing such wages is the cost of the cash paid

[18] See Dunn (1986), for example. Other references on the relation between firm size and wages include Abowd, Kramarz, and Margolis (1999), Bayard and Troske (1999), Brown and Medoff (1989), Lester (1967), and Thaler (1989).

out as wages. In a conglomerate, however, the different wages earned by different managers affect the envy-related utilities of these managers. On average, this causes a decline in their expected utilities, and the owner compensates for this via higher wages or inefficient investment. Thus, envy introduces an additional cost related to cross-sectional variation in wages. The owner trades off this cost against the cost of paying higher wages or making inefficient investments. Given these adjustments, the equilibrium cross-sectional variation in wages does not completely "absorb" the cross-sectional variation in reservation utilities.

Since utilities are not observable, the strong empirically-testable prediction of this model is the one relating to the cross-sectional variation in wages rather than inutilities. The second part of the proposition therefore provides conditions under which the cross-sectional variation in wages will be smaller in conglomerates than in single-segment firms. Although wage-related utility exhibits lower dispersion in conglomerates than in single-segment firms, one cannot immediately extrapolate this to lower wage dispersion in conglomerates. The reason is that envy in investment causes utility reduction for which even the manager with higher reservation utility - - who is already receiving a higher wage - - will need to be compensated with a further wage increase. But this manager's relatively high wage means that he has low marginal utility for wages, so providing even a small utility increase requires a relatively large wage increase for this manager. With risk-neutrality, the marginal utility of wages is constant, so a smaller dispersion in wage-related utility translates into a smaller wage dispersion. If the managers do not exhibit envy in investment levels or if the conglomerate divisions are in similar industries (so that optimal investment levels are roughly equal), the higher-ability manager does not suffer a cost of envy arising from lower investment and doesn't need to be compensated with higher wages. The three conditions mentioned in the proposition are sufficient conditions for wage dispersion to be smaller in conglomerates than in single-segment firms. We believe that this result will hold as long as either risk-aversion or envy in capital investment is small compared to envy in wages.

We are unaware of any existing empirical evidence on relative wage dispersions in conglomerates versus single-segment firms. Thus, we have a testable prediction that future empirical research could take to the data to potentially refute the theory.

4. OVERINVESTMENT IN DECENTRALIZED CAPITAL BUDGETING

We have seen that when the owner of the firm allocates capital to the divisions, the cost of envy among managers is reduced through a form of corporate socialism in capital allocation. Next, we examine how envy affects decentralized capital allocation, which may be necessitated by informational or observability constraints faced by the owner.

Consider the firm in the previous section but now suppose that the owner operates the firm at arm's length. The owner provides the total capital that can be invested by the two divisions but does not control or even observe the allocation of capital between the two divisions. Further, the owner cannot observe the cash flows of the two divisions separately. The owner can only observe the total value of the firm; this value depends on the aggregate cash flows of the two divisions.

The capital allocation is carried out by the two managers. The managers and the divisions are ex ante identical. At the beginning of the period, the owner raises total capital I and makes it available to the managers. Then the managers observe the productivity of capital in division 1 (θ_1) and in division 2 (θ_2) and use this information to demand capital *simultaneously* in Cournot fashion. Since the managers may disagree on how to allocate capital, we need a mechanism for conflict resolution. We consider a simple priority rule in which one of the two managers is randomly selected and his demand for capital is met subject to capital availability. Each manager is equally likely to have his demand for capital met. The other manager's demand is met completely if there is sufficient capital remaining after the manager selected first has invested in his division. If there is a shortfall of capital, the other manager gets to invest the capital remaining after the manager selected first has invested in his division. We are not attempting to solve for the

optimal mechanism. In principle, the owner can provide incentives to the managers to allocate capital in a particular fashion by conditioning their wages on all signals that are informative about capital allocation by the managers. However, that is nothing more than an indirect way for the owner to implement *centralized* capital allocation. To focus on a truly decentralized scheme, we assume that the only information available to the owner is the ex post value of the firm, and the owner incents the managers by making their wages contingent on the final value of the firm. The wage of each manager is an increasing function $W(V)$ of the ex post value of the firm (gross of the managers' wages).

Consider first the benchmark case in which each manager cares only about his wage. That is, the managers do not envy each other. In this case, the expected utility of either manager is

$$E\left[u\left(W\left(V\right)\right)\middle| V=\theta_1 f\left(I_1\right)+\theta_2 f\left(I_2\right)+\varepsilon_1+\varepsilon_2-I_1-I_2\right] \tag{13}$$

Thus, both managers want to maximize $\theta_1 f\left(I_1\right)+\theta_2 f\left(I_2\right)-I_1-I_2$. The reason is that firm value is increasing in this expression in a first-order-stochastic-dominance sense. However, the above expression is maximized when I_1 and I_2 are chosen according to (9). Thus, in the absence of envy, the managers choose the same capital allocation $\left(I_1^*, I_2^*\right)$ in a decentralized system that the owner would have chosen in a centralized system. This observation is important because it means that we have a setup in which any distortions attributable to decentralization will be solely due to envy.

Now suppose that the managers envy each other and utility of manager *j* is given by (10). Since the managers have different objective functions in this case, their demands for capital may conflict. We shall first solve the simple case in which capital is not constrained. This means that the total capital available is more than sufficient to accommodate the highest possible demand for capital by each manager. In this case, it does not matter which manager's demand for capital is

met first because each manager will get the amount of capital he demands for investment in his division.

Suppose capital demands $\left(I_1^{**}, I_2^{**}\right)$ constitute an equilibrium. Then, the incentive compatibility condition for manager 1 requires that I_1^{**} be a value of I_1 that maximizes

$$E\left[u\left(W\left(V\right)\right)+\phi\left(W\left(V\right)-W\left(V\right)\right)+\psi\left(I_1-I_2^{**}\right)\mid V=\theta_1 f\left(I_1\right)+\theta_2 f\left(I_2^{**}\right)+\varepsilon_1+\varepsilon_2-I_1-I_2^{**}\right] \quad (14)$$

Similarly, the incentive compatibility condition for manager 2 requires that I_2^{**} be a value of I_2 that maximizes

$$E\left[u\left(W\left(V\right)\right)+\phi\left(W\left(V\right)-W\left(V\right)\right)+\psi\left(I_2-I_1^{**}\right)\mid V=\theta_1 f\left(I_1^{**}\right)+\theta_2 f\left(I_2\right)+\varepsilon_1+\varepsilon_2-I_1^{**}-I_2\right] \quad (15)$$

Proposition 6: *In a decentralized capital allocation system, when managers envy each other, they invest more capital than they would in the absence of envy.*

The intuition for the proposition is straightforward. When the managers do not envy each other, they want to maximize firm value because doing so maximizes their wages. However, when the managers envy each other, they are not interested only in maximizing wages; each also cares about the capital allocation in his division relative to that in the other division. Thus, each manager is willing to increase capital allocation in his division beyond the envy-free level even if it reduces the NPV of investment and decreases his wage as long as this wage decrease is less than the increase in the manager's envy-related utility from acquiring additional capital.

Next we introduce a constraint on capital. The simultaneous-move game is the same as in the previous case. However, with limited capital, a conflict arises if there is insufficient capital to meet the capital demands of the two managers. As explained earlier, the "rationing" rule is a random priority-based rule in which each manager is equally likely to be allowed to take as much capital as desired, subject to total capital availability. The other manager gets the minimum of his capital demand and the capital remaining after the first manager has taken his share.

Suppose the equilibrium capital demands by managers 1 and 2 are I_1 and I_2, respectively. If the demand for capital by manager 1 is met first, manager 1 gets to invest I_1 in his division while manager 2 gets to invest $\min(I_2, I - I_1)$ in his division. Similarly, if the demand for capital by manager 2 is met first, manager 2 gets to invest I_2 in his division while manager 1 gets to invest $\min(I_1, I - I_2)$ in his division. Since the managers expect the two cases are equally likely, Manager 1 chooses $I_1 \le I$ to maximize the following objective:

$$\begin{aligned}
&0.5\psi\left(I_1 - \min\left(I_2, I - I_1\right)\right) + 0.5\psi\left(\min\left(I_1, I - I_2\right) - I_2\right) + \\
&0.5E\left[u\left(W\left(V\right)\right) \mid V = \theta_1 f\left(I_1\right) + \theta_2 f\left(\min\left(I_2, I - I_1\right)\right) + \varepsilon_1 + \varepsilon_2 - I_1 - \min\left(I_2, I - I_1\right)\right] + \\
&0.5E\left[u\left(W\left(V\right)\right) \mid V = \theta_1 f\left(\min\left(I_1, I - I_2\right)\right) + \theta_2 f\left(I_2\right) + \varepsilon_1 + \varepsilon_2 - \min\left(I_1, I - I_2\right) - I_2\right].
\end{aligned}$$

Similarly, Manager 2 chooses $I_2 \le I$ to maximize the following objective:

$$\begin{aligned}
&0.5\psi\left(\min\left(I_2, I - I_1\right) - I_1\right) + 0.5\psi\left(I_2 - \min\left(I_1, I - I_2\right)\right) + \\
&0.5E\left[u\left(W\left(V\right)\right) \mid V = \theta_1 f\left(I_1\right) + \theta_2 f\left(\min\left(I_2, I - I_1\right)\right) + \varepsilon_1 + \varepsilon_2 - I_1 - \min\left(I_2, I - I_1\right)\right] + \\
&0.5E\left[u\left(W\left(V\right)\right) \mid V = \theta_1 f\left(\min\left(I_1, I - I_2\right)\right) + \theta_2 f\left(I_2\right) + \varepsilon_1 + \varepsilon_2 - \min\left(I_1, I - I_2\right) - I_2\right].
\end{aligned}$$

Proposition 7: *In a decentralized capital allocation system, when managers envy each other, capital constraints increase managers' tendency to overinvest. Suppose the managers' capital demands are* I_1^{**} *and* I_2^{**} *when there is no constraint on capital available. Then if available capital is* $I = I_1^{**} + I_2^{**}$*, managers demand* $I_1 > I_1^{**}$ *and* $I_2 > I_2^{**}$.

The intuition is as follows. The capital choice of each manager maximizes the sum of his utility from wages (which is increasing in firm value) and the envy-related utility based on relative capital allocation. The utility from wages can be increased by investing efficiently to increase firm value. However, the envy-related utility can be increased either by increasing one's own capital allocation or decreasing the other manager's capital allocation. Proposition 6 shows that managers overinvest to increase their capital allocation even if it reduces firm value. Proposition 7 shows that this overinvestment propensity is exacerbated by capital constraints. If capital is constrained, the benefit to a manager of demanding additional capital is twofold. One is a direct increase in the manager's utility because capital is a good in his utility function. This is

true even without a capital constraint. But the capital constraint introduces another advantage of demanding additional capital, which is to reduce the capital available to the other manager.[19] This further increases envy-related utility. Envy thus causes managers to behave in a way that makes them appear vindictive, and a *perceived capital constraint will make capital feel even scarcer than it is in reality*.

5. CONCLUSION

We have provided a framework for modeling envy in corporate finance. Envious agents are viewed as having utility increasing in their own consumption and resources and decreasing in the consumption and resources of those whom they envy. We explore the effect of envy on investment allocation in firms. We have two main results. First, envy leads to corporate socialism when there is centralized capital allocation. The owner of the firm reduces the cost of envy arising from disparate investment allocations to divisions with different capital productivities by smoothing investments across divisions. Second, in a decentralized capital allocation system, envious managers will overinvest. The tendency to overinvest increases when the total capital available to the managers is limited. Thus, capital constraints increase investment distortions across the divisions of a conglomerate.

We can draw numerous additional empirical implications from our analysis. First, in a centralized capital allocation system, the owner must compensate managers for envy by paying them higher wages or through corporate socialism. As a result, envy reduces firm value. This reduction in firm value is greater in firms where envy is greater. Specifically, the reduction in firm value due to envy is greater in firms where investment opportunities across divisions are more diverse, and in firms with more divisions. Second, the *relative* reduction in firm value due to envy will be an increasing function of the number of divisions in the firm. Third, average managerial compensation will be higher in conglomerates than in single-segment firms, and the

[19] This aspect of the manager's behavior is consistent with the experimental evidence in Zizzo and Oswald (2001).

cross-sectional variation in wages will be greater in single-segment firms than in conglomerates. Finally, our result that investment distortions are worsened by capital constraints leads to the prediction that firms will overinvest in order to limit inefficient investment arising from envy among divisional managers. Such aggregate overinvestment will be greater when the number of managers who share resources is larger.

That envy is an aspect of human behavior is hard to dispute. It is interesting that the recognition of envy helps to rationalize corporate investment distortions so directly. But we have merely scratched the surface. We believe that the introduction of envy into preferences has the potential to produce a rich harvest of insights in corporate finance.

APPENDIX

Proof of Proposition 1: The owner's problem is

$$\underset{I_1,I_2,W_1,W_2}{Max}\ E\left[g(\theta_1)f(I_1(\Theta))+g(\theta_2)f(I_2(\Theta))-I_1(\Theta)-I_2(\Theta)-W_1(\Theta)-W_2(\Theta)\right] \quad \text{(A1)}$$

such that

$$E\left[u(W_1(\Theta))+\phi(W_1(\Theta)-W_2(\Theta))+\psi(I_1(\Theta)-I_2(\Theta))\right] \ \geq \ U^0, \quad \text{(A2)}$$

$$E\left[u(W_2(\Theta))+\phi(W_2(\Theta)-W_1(\Theta))+\psi(I_2(\Theta)-I_1(\Theta))\right] \ \geq \ U^0, \text{ and} \quad \text{(A3)}$$

$$I_1(\Theta)+I_2(\Theta)\leq I\,. \quad \text{(A4)}$$

Let $\lambda_1 \geq 0$, $\lambda_2 \geq 0$, and $\lambda_3 \leq 0$ be the Lagrange multipliers corresponding to (A2), (A3), and (A4), respectively. The first order conditions are:

$$g(\theta_1)f'(I_1(\Theta))-1+\lambda_1\psi'(I_1(\Theta)-I_2(\Theta))-\lambda_2\psi'(I_2(\Theta)-I_1(\Theta))=\lambda_3 \quad \text{(A5)}$$

$$g(\theta_2)f'(I_2(\Theta))-1-\lambda_1\psi'(I_1(\Theta)-I_2(\Theta))+\lambda_2\psi'(I_2(\Theta)-I_1(\Theta))=\lambda_3 \quad \text{(A6)}$$

$$\lambda_1\{u'(W_1(\Theta))+\phi'(W_1(\Theta)-W_2(\Theta))\}-\lambda_2\phi'(W_2(\Theta)-W_1(\Theta))=1 \quad \text{(A7)}$$

$$-\lambda_1\phi'(W_1(\Theta)-W_2(\Theta))+\lambda_2\{u'(W_2(\Theta))+\phi'(W_2(\Theta)-W_1(\Theta))\}=1 \quad \text{(A8)}$$

From (A7) and (A8), $W_1(\Theta)=W_1$ and $W_2(\Theta)=W_2$ where W_1 and W_2 are the unique solutions to (A7) and (A8). By the symmetry of the problem, $W_1 = W_2 = W$. Then,

$$u'(W)=1/\lambda_1=1/\lambda_2\,.$$

Now, consider $\theta_1 > \theta_2$. Then, $I_1^*(\Theta)>I_2^*(\Theta)$ from (9). We must also have

$$I_1(\Theta)>I_2(\Theta). \quad \text{(A9)}$$

If $I_1 \leq I_2$, then (A5) and (A6) yield the following contradiction:

$$\lambda_3 = g(\theta_1)f'(I_1(\Theta)) - 1 + \lambda_1\psi'(I_1(\Theta) - I_2(\Theta)) - \lambda_1\psi'(I_2(\Theta) - I_1(\Theta))$$
$$> g(\theta_2)f'(I_2(\Theta)) - 1 - \lambda_1\psi'(I_1(\Theta) - I_2(\Theta)) + \lambda_1\psi'(I_2(\Theta) - I_1(\Theta)) = \lambda_3 .$$

Combining (A5), (A6), and (A9) yields

$$g(\theta_1)f'(I_1(\Theta)) > g(\theta_2)f'(I_2(\Theta)) . \tag{A10}$$

Equality (9) and inequality (A10) can hold only if $I_1 < I_1^*, I_2 \geq I_2^*$ or $I_1 \leq I_1^*, I_2 > I_2^*$, both consistent with the Proposition. The other alternatives are $I_1 < I_1^*, I_2 < I_2^*$ and $I_1 > I_1^*, I_2 > I_2^*$. The first one is not possible because increasing I_2 will increase firm value. The reason is that increasing I_2 not only reduces envy between the managers and thereby wage bill by bringing I_1 and I_2 closer but also increases NPV of division 1 by bringing investment closer to I_2^*. Similarly, $I_1 > I_1^*, I_2 > I_2^*$ is not possible.

Let $V(\Theta)$ be the firm value corresponding to the solution of problem (A1)-(A4). Applying the envelope theorem for the constrained maximization case, we get:

$$\frac{\partial V(\Theta)}{\partial \theta_1} = g'(\theta_1)f(I_1(\Theta)) .$$

If we similarly define firm value $V^*(\Theta)$ for the no-envy case, then

$$\frac{\partial V^*(\Theta)}{\partial \theta_1} = g'(\theta_1)f^*(I_1(\Theta)) .$$

Combining the previous two equations, we have:

$$\frac{\partial}{\partial \theta_1}\{V^*(\Theta) - V(\Theta)\} = g'(\theta_1)\{f^*(I_1(\Theta)) - f(I_1(\Theta))\} > 0 .$$

Similarly,

$$\frac{\partial}{\partial \theta_2}\{V^*(\Theta) - V(\Theta)\} = g'(\theta_2)\{f^*(I_2(\Theta)) - f(I_2(\Theta))\} < 0 . \tag{A11}$$

■

Proof of Proposition 2: Since the productivities θ_1 and θ_2 are normal with correlation ρ,

$$\left(\theta_2|\theta_1\right) \sim \rho\theta_1 + \sqrt{1-\rho^2}z$$

where $z \sim N(0, \sigma^2)$ and z is independent of θ_1. The reduction in firm value due to envy is

$$V^*(\rho) - V(\rho) = E_{\theta_1}\left[E_z\left[V^*(\Theta) - V(\Theta)\middle|\theta_2 = \rho\theta_1 + \sqrt{1-\rho^2}z\right]\right]$$

Now suppose the correlation between the two divisions increases to $\hat{\rho} > \rho$. Then, the productivity $\hat{\theta}_2$ of division 2, conditional on productivity of division 1, is distributed as:

$$\left(\hat{\theta}_2|\theta_1\right) \sim \hat{\rho}\theta_1 + \sqrt{1-\hat{\rho}^2}z$$

For the moment assume that the second-best contract specifying wages and investment is unchanged. Then,

$$V^*(\hat{\rho}) - V(\hat{\rho}) = E_{\theta_1}\left[E_z\left[V^*(\hat{\Theta}) - V(\hat{\Theta})\middle|\hat{\theta}_2 = \hat{\rho}\theta_1 + \sqrt{1-\hat{\rho}^2}z\right]\right]$$

where $\hat{\Theta} \equiv \left(\theta_1, \hat{\theta}_2\right)$. Taking the difference of the previous two equations, we obtain:

$$\begin{aligned}
&V^*(\hat{\rho}) - V(\hat{\rho}) - V^*(\rho) - V(\rho) \\
&= E_{\theta_1,z}\left[\left\{V^*\left(\theta_1, \hat{\theta}_2\right) - V\left(\theta_1, \hat{\theta}_2\right)\right\} - \left\{V^*(\theta_1, \theta_2) - V(\theta_1, \theta_2)\right\}\middle| z < \theta_1\right] \\
&\quad + E_{\theta_1,z}\left[\left\{V^*\left(\theta_1, \hat{\theta}_2\right) - V\left(\theta_1, \hat{\theta}_2\right)\right\} - \left\{V^*(\theta_1, \theta_2) - V(\theta_1, \theta_2)\right\}\middle| z > \theta_1\right] \;<\; 0
\end{aligned}$$

The inequality follows because both terms on the left side are negative. In the first term, $\theta_2 < \hat{\theta}_2 < \theta_1$ so (A11) implies that $V^*\left(\theta_1, \hat{\theta}_2\right) - V\left(\theta_1, \hat{\theta}_2\right) < V^*(\theta_1, \theta_2) - V(\theta_1, \theta_2)$. In the second term, $\theta_2 > \hat{\theta}_2 > \theta_1$, so Proposition 1 implies $V^*\left(\theta_1, \hat{\theta}_2\right) - V\left(\theta_1, \hat{\theta}_2\right) < V^*(\theta_1, \theta_2) - V(\theta_1, \theta_2)$.

Thus, the reduction in firm value diminishes as the correlation increases, under the assumption that the second-best contract is unchanged. An *optimal* second-best contract can further increase firm value. For example, the cost of envy borne by the managers decreases as the correlation among divisions increases, which permits the wages of managers to be reduced. ■

Proof of Proposition 3: We shall show that the fractional decline in firm value due to envy increases as the number of divisions increases. For a meaningful comparison across firms with

different numbers of divisions, we shall not consider any capital constraints. Consider a firm with n ex ante identical divisions, $n > 1$ with the production function of each division given by (6). The manager of each division envies the manager of every other division. Let $I_j(\Theta)$ and $W_j(\Theta)$ denote the investment and wage for division j when the productivities of the different divisions are $\Theta \equiv (\theta_1,\ldots,\theta_n)$. The owner's problem is

$$\underset{\{I_j(\Theta),W_j(\Theta)\}}{Max} E\left[\sum\left\{g(\theta_j)f\left(I_j(\Theta)\right)-I_j(\Theta)-W_j(\Theta)\right\}\right] \tag{A12}$$

such that

$$E\left[u\left(W_j(\Theta)\right)+\sum_{k\neq j}\left\{\phi\left(W_j(\Theta)-W_k(\Theta)\right)+\psi\left(I_j(\Theta)-I_k(\Theta)\right)\right\}\right] \quad = \quad U^0, \quad j=1..n\,, \tag{A13}$$

The individual rationality (IR) constraints in (A13) hold as equalities because otherwise the wages of one or more managers can be reduced to increase firm value. Let the value of the firm be $V(n)$. The expected NPV of each division net of its manager's wage is $V(n)/n$. Now consider a firm with divisions 1 to n-1. Suppose the new wage policy $\hat{W}_j$ and investment policy $\hat{I}_j$ are chosen such that

$$\hat{W}_j(\theta_1,\ldots,\theta_{n-1}) \sim W_j(\theta_1,\ldots,\theta_{n-1},\theta_n), \quad \hat{I}_j(\theta_1,\ldots,\theta_{n-1}) \sim I_j(\theta_1,\ldots,\theta_{n-1},\theta_n)$$

Then the expected wage and expected NPV of each division equals $V(n)/n$. However, since the managers of division 1 to n-1 do not envy the manager of division n, their expected utilities increase.

$$\begin{aligned}
&E\left[u\left(\hat{W}_j(\theta_1..\theta_{n-1})\right)+\sum_{k\neq j,n}\left\{\phi\left(\hat{W}_j(\theta_1..\theta_{n-1})-\hat{W}_k(\theta_1..\theta_{n-1})\right)+\psi\left(\hat{I}_j(\theta_1..\theta_{n-1})-\hat{I}_k(\theta_1..\theta_{n-1})\right)\right\}\right] \\
&= E\left[u\left(W_j(\Theta)\right)+\sum_{k\neq j,n}\left\{\phi\left(W_j(\Theta)-W_k(\Theta)\right)+\psi\left(I_j(\Theta)-I_k(\Theta)\right)\right\}\right] \\
&= E\left[u\left(W_j(\Theta)\right)+\sum_{k\neq j}\left\{\phi\left(W_j(\Theta)-W_k(\Theta)\right)+\psi\left(I_j(\Theta)-I_k(\Theta)\right)\right\}\right] \\
&\quad -E\left[\phi\left(W_j(\Theta)-W_k(\Theta)\right)+\psi\left(I_j(\Theta)-I_k(\Theta)\right)\right]
\end{aligned}$$

$$= U^0 - E\left[\phi\left(W_j(\Theta) - W_k(\Theta)\right) + \psi\left(I_j(\Theta) - I_k(\Theta)\right)\right] \quad > \quad U^0 \quad .$$

The last equality uses (A12) while the inequality follows because $\phi(0) = \psi(0) = 0$, $\phi'' < 0$, and $\psi'' < 0$. Thus, the wage of each manager can be reduced to further increase firm value. Thus,

$$\frac{V(n-1)}{n-1} > \frac{V(n)}{n}. \tag{A14}$$

In the absence of envy, the wage and investment for each division is independent of the productivities of the other divisions, so we have:

$$\frac{V^*(n-1)}{n-1} = \frac{V^*(n)}{n}. \tag{A15}$$

Combining (A14) and (A15),

$$\frac{V(n-1)}{V^*(n-1)} > \frac{V(n)}{V^*(n)} \quad .$$

Further,

$$V^*(n-1) - V(n-1) = V^*(n-1)\left\{1 - \frac{V(n-1)}{V^*(n-1)}\right\} < V^*(n)\left\{1 - \frac{V(n)}{V^*(n)}\right\} = V^*(n) - V(n) \quad .$$

■

Proof of Proposition 4: We showed in the proof of Proposition 1 that the wages are equal and constant. Using this fact and adding (A2) and (A3), we get:

$$2u(W) + E\left[\psi\left(I_1(\Theta) - I_2(\Theta)\right) + \psi\left(I_2(\Theta) - I_1(\Theta)\right)\right] \quad \geq \quad 2U^0 .$$

Since $\psi(0) = 0$, and $\psi'' < 0$, it follows that $u(W) > U^0$. Comparison with (10) shows that $W > W^*$. ■

Proof of Proposition 5: Consider the owner's problem (A1)-(A4) with the exception that the reservation utility of the manager of division 1, U^1, exceeds the reservation utility U^2 of the manager of division 2. That is,

$$U^1 > U^2 . \tag{A16}$$

Thus, (A2) and (A3) are replaced by

$$u(W_1) + \phi(W_1 - W_2) + E[\psi(I_1(\Theta) - I_2(\Theta))] \quad = \quad U^1, \tag{A17}$$

$$u(W_2) + \phi(W_2 - W_1) + E[\psi(I_2(\Theta) - I_1(\Theta))] \quad = \quad U^2, \text{ and} \tag{A18}$$

In the absence of envy, the wages are determined as follows:

$$u(W_1^*) = U^1, \quad u(W_2^*) = U^2 . \tag{A19}$$

With envy, the wages will be constant, W_1 and W_2, following the arguments in the proof of Proposition 1. We first show that $W_1 > W_2$. Suppose counterfactually that this is not true, so that

$$W_1 \leq W_2. \tag{A20}$$

Then, taking the difference of (A7) and (A8), we get:

$$\lambda_1 \{u'(W_1) + 2\phi'(W_1 - W_2)\} = \lambda_2 \{u'(W_2) + 2\phi'(W_2 - W_1)\} \tag{A21}$$

Combining (A20) and (A21), we get

$$\lambda_1 \leq \lambda_2 . \tag{A22}$$

The investments in the two divisions are determined by (A5) and (A6). Substituting (A22) shows that there is a bias in investment allocation towards division 2. Specifically, for any given θ^a and θ^b,

$$I_1(\theta^a, \theta^b) \leq I_2(\theta^b, \theta^a), \quad I_1(\theta^b, \theta^a) \leq I_2(\theta^a, \theta^b).$$

This implies

$$\begin{aligned} &\psi(I_1(\theta^a, \theta^b) - I_2(\theta^a, \theta^b)) + \psi(I_1(\theta^b, \theta^a) - I_2(\theta^b, \theta^a)) \\ &\leq \psi(I_2(\theta^a, \theta^b) - I_1(\theta^a, \theta^b)) + \psi(I_2(\theta^b, \theta^a) - I_1(\theta^b, \theta^a)) \quad . \end{aligned}$$

Since θ_1 and θ_2 are identically distributed, this leads to

$$E[\psi(I_1(\Theta)-I_2(\Theta))] \le E[\psi(I_2(\Theta)-I_1(\Theta))]. \quad \text{(A23)}$$

But (A20) and (A23) contradict (A16), (A17) and (A18). Thus,

$$W_1 > W_2. \quad \text{(A24)}$$

Using arguments similar to those following (A20), we get

$$E[\psi(I_1(\Theta)-I_2(\Theta))] > E[\psi(I_2(\Theta)-I_1(\Theta))]. \quad \text{(A25)}$$

Substituting (A24) and (A25) in (A17) and (A18), we get

$$u(W_1)-u(W_2) < U^1 - U^2. \quad \text{(A26)}$$

Comparing (A19) and (A26) yields the first part of the proposition. With risk neutrality,

$$u(W_1)-u(W_2) < u(W_1^*)-u(W_2^*) \;\Rightarrow\; W_1 - W_2 < W_1^* - W_2^*.$$

If managers do not exhibit envy in capital investment, (A17), (A18), and (A19) reduce to

$u(W_1)+\phi(W_1-W_2) \;=\; u(W_1^*)$, and

$u(W_2)+\phi(W_2-W_1) \;=\; u(W_2^*)$

which immediately yield $W_1^* > W_1 > W_2 > W_2^*$. Finally, if investment opportunities are identical across the divisions, we can use arguments similar to those following (A20) to show that $I_1 > I_2$ so that (A17), (A18), and (A19) reduce to

$u(W_1)+\phi(W_1-W_2) \;<\; u(W_1^*)$, and

$u(W_2)+\phi(W_2-W_1) \;>\; u(W_2^*)$

which again yields $W_1^* > W_1 > W_2 > W_2^*$. ■

Proof of Proposition 6: The first-order condition for capital choice by manager 1 is

$$\psi'\left(I_1 - I_2^{**}\right) + \left\{\theta_1 f'\left(I_1^{**}\right) - 1\right\} \times$$
$$E\left[u'\left(W\left(V\right)\right)W'\left(V\right) \mid V = \theta_1 f\left(I_1\right) + \theta_2 f\left(I_2^{**}\right) + \varepsilon_1 + \varepsilon_2 - I_1 - I_2^{**}\right] = 0 .$$

Since the functions ψ, *u* and *W* are increasing, this yields,

$$\theta_1 f'\left(I_1^{**}\right) < 1 .$$

Comparing with (9) shows that $I_1^{**} > I_1^{*}$. The proof for the investment in second division is similar. ■

Proof of Proposition 7: From Proposition 6, if capital is unlimited, the managers demand I_1^{**} and I_2^{**}, respectively such that

$$\theta_1 f\left(I_1^{**}\right) < 1, \quad \theta_2 f\left(I_2^{**}\right) < 1 . \tag{A27}$$

Now suppose total capital is limited to $I = I_1^{**} + I_2^{**}$. We must show that it is an equilibrium for manager 1 to demand $I_1 > I_1^{**}$ and for manager 2 to demand $I_2 > I_2^{**}$. An equilibrium is defined by $I_1^R\left(I_2\right) = I_1$ and $I_1^R\left(I_2\right) = I_1$ where I_1^R and I_2^R are the best response functions of managers 1 and 2 respectively.

First we show that

$$\hat{I}_1 \equiv I_1^R\left(I_2^{**}\right) > I_1^{**} . \tag{A28}$$

Define $U_1(I_1, I_2)$ as the expected utility of manager 1 when the capital allocation is I_1 in division 1 and I_2 in division 2. Since the equilibrium capital allocation with unlimited capital is $\left(I_1^{**}, I_2^{**}\right)$, we have

$$U_1\left(I_1^{**}, I_2^{**}\right) \geq U\left(I_1, I_2^{**}\right) \quad \forall I_1 \tag{A29}$$

With limited capital, if manager 2 demands I_2^{**} while manager 1 demands less than I_1^{**}, the capital constraint does not bind and (A29) holds. This shows

$$I_1^R\left(I_2^{**}\right) \geq I_1^{**} . \tag{A30}$$

Consider capital demands $\left(I_1^{**}, I_2^{**}\right)$. The derivative of the expected utility of manager 1 with respect to his demand is

$$\begin{aligned}
&\frac{\mathrm{d}}{\mathrm{d}I_1}\left\{0.5U_1\left(I_1, I-I_1\right)+0.5U_1\left(I-I_2^{**}, I_2^{**}\right)\right\}_{I_1=I_1^{**}} \\
&= 0.5\left[2\psi'\left(2I_1-I\right)+\left\{\theta_1 f'\left(I_1\right)-\theta_2 f'\left(I-I_1\right)\right\}E\left[u\left(W\left(\theta_1 f\left(I_1\right)+\theta_2 f\left(I-I_1\right)+\varepsilon_1+\varepsilon_2-I\right)\right)\right]\right]_{I_1=I_1^{**}} \\
&= 0.5\left[2\psi'\left(I_1^{**}-I_2^{**}\right)+\left\{\theta_1 f'\left(I_1^{**}\right)-\theta_2 f'\left(I_2^{**}\right)\right\}E\left[u\left(W\left(\theta_1 f\left(I_1^{**}\right)+\theta_2 f\left(I_2^{**}\right)+\varepsilon_1+\varepsilon_2-I\right)\right)\right]\right] \\
&= 0.5\left[\psi'\left(I_1^{**}-I_2^{**}\right)+\left\{\theta_1 f'\left(I_1^{**}\right)-1\right\}E\left[u\left(W\left(\theta_1 f\left(I_1^{**}\right)+\theta_2 f\left(I_2^{**}\right)+\varepsilon_1+\varepsilon_2-I\right)\right)\right]\right]+ \\
&\quad 0.5\left[\psi'\left(I_1^{**}-I_2^{**}\right)+\left\{\theta_2 f'\left(I_2^{**}\right)-1\right\}E\left[u\left(W\left(\theta_1 f\left(I_1^{**}\right)+\theta_2 f\left(I_2^{**}\right)+\varepsilon_1+\varepsilon_2-I\right)\right)\right]\right] \\
&= 0.5\left[\psi'\left(I_1^{**}-I_2^{**}\right)+\left\{\theta_2 f'\left(I_2^{**}\right)-1\right\}E\left[u\left(W\left(\theta_1 f\left(I_1^{**}\right)+\theta_2 f\left(I_2^{**}\right)+\varepsilon_1+\varepsilon_2-I\right)\right)\right]\right] \\
&> 0
\end{aligned} \tag{A31}$$

Here the last equality uses the first-order-condition derived from (A29) while the inequality uses (A27). The inequality (A28) follows from (A30) and (A31). Next we show that

$$I_1^R\left(I_2\right) > I_1^{**} \quad \forall I_2 \geq I_2^{**} . \tag{A32}$$

Suppose this is not true and there exists $I_2 > I_2^{**}$ such that $I_1^R\left(I_2\right) \leq I_1^{**}$. Using (A28) and the continuity of the I_1^R function, there must exist $\hat{I}_2 > I_2^{**}$ such that

$$I_1^R\left(\hat{I}_2\right) = I_1^{**} . \tag{A33}$$

Inequality (A31) and the incentive compatibility of manager 1 in (A28) imply

$$0.5U_1\left(\hat{I}_1, I-\hat{I}_1\right)+0.5U_1\left(I-I_2^{**}, I_2^{**}\right) > 0.5U_1\left(I_1^{**}, I-I_1^{**}\right)+0.5U_1\left(I-I_2^{**}, I_2^{**}\right). \tag{A34}$$

Similarly, the incentive compatibility of manager 1 in (A33) implies

$$0.5U_1\left(I_1^{**}, I-I_1^{**}\right)+0.5U_1\left(I-\hat{I}_2, \hat{I}_2\right) \geq 0.5U_1\left(\hat{I}_1, I-\hat{I}_1\right)+0.5U_1\left(I-\hat{I}_2, \hat{I}_2\right). \tag{A35}$$

(A34) and (A35) are contradictory, so (A32) must hold. Similarly, we can show that

$$I_2^R\left(I_1\right) > I_2^{**} \quad \forall I_1 \geq I_1^{**} . \tag{A36}$$

Combining (A33) and (A36), we get $I_1^R\left(I_2^R\left(I_1^{**}\right)\right) > I_1^{**}$. Further, $I_1^R\left(I_2^R\left(I\right)\right) > I$. By continuity, there exists $I_1 > I_1^{**}$ such that $I_1^R\left(I_2^R\left(I_1\right)\right) = I_1$. Then, capital demands I_1 and $I_2 = I_2^R\left(I_1\right) > I_2^{**}$ constitute an equilibrium. ■

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