Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Banking & Finance 29 (2005) 3061–3073
Journal of BANKING & FINANCE
www.elsevier.com/locate/jbf

Capital market equilibrium with externalities, production and heterogeneous agents

Andrea Beltratti *

Istituto di Economia Politica, Università Commerciale L. Bocconi, Via Sarfatti 25, Milano 20100, Italy

Received 22 March 2004; accepted 16 November 2004
Available online 19 January 2005

Abstract

The paper studies general equilibrium in an economy with externalities, production and heterogeneous agents. The model developed builds on Brock [Brock, W.A., 1982. Asset prices in a production economy. In: McCall, J.J. (Ed.), The Economics of Information and Uncertainty. University of Chicago Press, Chicago, pp. 1–43] and Merton [Merton, R.C., 1987. A simple model of capital market equilibrium with incomplete information. Journal of Finance 42, 483–510]; it involves both a stock market and a market for loans, together with negative externalities produced by a subset of firms. Importantly, the technological production structure of the firms is reflected in the properties of the shares traded in the stock market. Agents are heterogeneous in their financial choices, potentially discriminating against the firms producing a negative externality. The model sheds light on the utility costs of the discriminating behavior and on the impact on the price of the stock issued by the firm which is responsible for the externality. The model is used to study the factors which may magnify or reduce the impact of discrimination. A set of discriminated firms may be seriously affected only if the discriminating investors command a large portion of overall wealth and/or they do not represent important diversification instruments. The model can be applied to understanding the effects of socially responsible investment, whereby investors discriminate against companies belonging to some sectors which are perceived as socially dangerous or unethical.

* Tel.: +39 2 5836 5306; fax: +39 2 5836 5343.
E-mail address: andrea.beltratti@uni-bocconi.it

0378-4266/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.jbankfin.2004.11.004

JEL classification: D50; H23; H41
Keywords: Externalities; General equilibrium with production; Heterogeneous investors; Social responsibility

1. Introduction

This paper develops a two-period general equilibrium model combining the following features: uncertainty, production, externalities and heterogeneous agents. Agents are heterogeneous in their willingness to buy the financial assets issued by two classes of firms and as a consequence are themselves divided in two classes. Agents in one class discriminate against the financial assets issued by firms belonging to the externality-producing sector. They discriminate by not buying the assets issued by the firms. In so doing, they restrict their investment opportunity set and therefore their expected utility, given the level of production of the firms. However, in general equilibrium the production levels are not given, but optimally chosen by the firms. A change in the structure of relative prices of financial assets may affect the production decisions of the firms and the amount of externality generated in the economy. We assume that agents are atomistic, in the sense of believing each of them is too small to affect the general equilibrium of the economy. Discrimination is therefore not an individually rational choice, because it is decided by agents taking equilibrium prices and quantities as given. However, it might turn out to be ex post welfare-improving, if the effects on the demand for financial assets are relevant for modifying equilibrium prices and quantities.

We believe that the implications of the model may be relevant for studying various cases of restrictions imposed to some classes of institutional investors, for example restrictions associated with holdings small stocks, private equity, hedge funds. In these cases such financial organizations have to take into account external regulations presumably aimed at protecting the final individual stakeholders. The model may also be used to study the issue of socially responsible investment (SRI), which may be defined as a style of making portfolio choices which go beyond the analysis of the probability distribution of returns to also involve a study of the social impact of the production activities carried out by the firms having issued the financial assets. The typical case is that of a mutual or pension fund manager excluding tobacco stocks or polluting stocks a priori from his asset allocation. [1] This investment style is not externally imposed by regulations, but is chosen by the investor. It involves in general an expected utility loss to those using it, associated with the decrease in the investment opportunity set. Contrary to the case of institutional investors targeting firms for corporate governance reasons, socially responsible investors in general do

[1] A good example dates from February 22, 2002, with the pension fund Calpers deciding to stop investing in Thailand, Indonesia, Malaysia and the Philippines because of violations of human and worker rights. Also typical is an index-producer such as Dow Jones excluding firms from a socially responsible index.

not expect to obtain a positive payoff from their action of discrimination, especially when they are aimed at general ethical (e.g. human rights) or environmental (e.g. sustainable development) issues. This of course does not mean that socially responsible investors ignore the return and risk from their investment. They can still be modelled as expected utility maximizers, who however are willing to restrict their investment opportunity set in order to pursue more general objectives.

But how effective is discrimination in financial markets? Consider a case where the supply function of shares of a firm is vertical and the demand function is negatively sloped. Then discrimination may shift the demand function down and decrease the equilibrium price. However one could argue that the price of a stock is the present discounted value of its fundamentals. In this case the decreased demand on the part of one group of investors would be rapidly offset by an increased demand on the part of another group who would perceive the opportunity to buy stocks at a market price lower than value. Moreover, one has to take into account the existence of a multiplicity of financial channels linking firms and savers. Discrimination uniquely targeted at stocks may miss the relevance of lending on the part of other financial institutions.

The general equilibrium framework considered in this paper may be used in order to study this problem, because it allows for both production financed by loans and for stocks which are priced by means of discounting profits with a stochastic discount factor based on marginal consumption. Moreover the model allows for heterogeneity of discrimination among agents and the existence of lending, and, importantly, motivates the discriminating financial choice on the basis of an objective negative externality associated with one class of firms.

The plan of the paper is as follows. After this introduction, the second section describes the general equilibrium model. The third section comments on the results obtained from numerical solution of the model. The fourth section concludes.

2. A general equilibrium model of financial discrimination

2.1. Previous literature

The model involves two agents and two periods. It is similar in the description of the investment opportunity set to the model proposed by Brock (1982), which is an early production version of the simple Lucas (1978) tree economy. More recent models that introduce endogenous production in an asset pricing model are Naik (1994), Abel (2003), Dai (2000), Jermann and Quadrini (2002). Naik (1994) combines a finite-horizon economy with capital adjustment costs, time-varying risk and a representative investor with Epstein and Zin (1989) preferences to investigate the effects of changes in output uncertainty on the price of aggregate capital. The firm is financed exclusively through the stock market. Dai (2000) considers an infinite-horizon investor with consumption habit and time-non-separable preferences to explain the equity premium puzzle and other pricing anomalies. Jermann and Quadrini (2002) describe a production with capital and labor and less than full enforceability of the financing process to study the effects of a stock market boom on the constraints of the

production sector, showing that the resulting reallocation of labor increases aggregate average productivity.

Given that we are going to model a discrimination choice on the part of a subset of the population, it is crucial to allow for heterogeneity of agents. This heterogeneity however implies technical problems in the solution of the model. Lucas (1982) in a pure exchange economy can simply analyze the perfectly pooled equilibrium where the portfolio of the two agents are equal. The perfectly pooled equilibrium is not useful for our case because we want to study the consequences of heterogeneous behavior with respect to portfolio choice. Therefore we use a simple finite-horizon version of the model due to the technical difficulties associated with analysing heterogeneous agent, infinite-horizon models involving heterogeneous portfolios of financial assets, production and externalities. Our choice is also justified by referring to Merton (1987), which considers a two-period economy for studying a financial market populated by heterogeneous agents.

2.2. The model

In our two-period model, there are two classes of consumers, denoted with i and j, and two classes of firms, denoted with A and B. From now on we will refer simply to one consumer and one firm, but the interpretation is always that of an agent within each class. Consumer k, $k = i, j$, solves a two-period expected utility maximization problem:

$$\max u(c_{k,0}) + \delta E_0 u(c_{k,1}, D_k x_A), \tag{1}$$

$$c_{k,1} = \pi_{A,1} z_{k,A,0} + \pi_{B,1} z_{k,B,0} + r_{A,1} x_{k,A,0} + r_{B,1} x_{k,B,0}, \tag{2}$$

$$c_{k,0} = W_{k,0} - x_{k,A,0} - x_{k,B,0} - p_{A,0} z_{k,A,0} - p_{B,0} z_{k,B,0}. \tag{3}$$

Initial wealth $W_{k,0}$ is exogenous. At time 0 the agent selects consumption and resources invested in financial assets and consumes $c_{k,0}$ the remaining wealth, as described by Eq. (3). According to Eq. (2), final consumption $c_{k,1}$ is determined by the profits distributed by the two firms and by the interest paid on the loans. $\pi_{A,1}$ is the time 1 profit of firm A, defined in Eq. (10) below; $p_{A,0}$ is the time 0 market price of the stock issued by firm A; $z_{k,A,0}$ is the quantity of stocks of firm k held by investor A at time 0. A similar notation is used for firm B. $r_{A,1}$ is equal to 1 plus the rate of interest paid by firm A on the loan $x_{k,A,0}$ made by investor k at time 0. Determination of the interest rate and the price of the stocks obtains endogenously by market equilibrium. The utility function of one of the two consumers (conventionally, consumer i) depends negatively on the total amount of loans raised by firm A, $x_A = x_{i,A,0} + x_{j,A,0}$, that is $\partial u(c_{i,1}, x_A)/\partial x_A < 0$. D_k is a dummy variable, equal to 1 for consumer i and equal to 0 for consumer j, who is not affected by the negative externality occurring between production by one of the firms and one class of consumers.

As will be clear later, the specification implies that productive capital equals the value of loans, so this is a way to describe a negative external effect of the capital

used in production of one firm on welfare. Having the negative externality affecting consumption at time 1 allows the consumer to affect firm A, by means of financial discrimination, through the indirect effects of market prices.

The externality affects the first order condition of agent i if the utility function is non-separable in future consumption and the externality:

$$-u'(c_{i,0}) + E_0 u'(c_{i,1}, x_A) r_{A,1} = 0, \tag{4}$$

$$-u'(c_{i,0}) + E_0 u'(c_{i,1}, x_A) r_{B,1} = 0, \tag{5}$$

$$-p_{A,0} \times u'(c_{i,0}) + E_0 u'(c_{i,1}, x_A) \pi_{A,1} = 0, \tag{6}$$

$$-p_{B,0} \times u'(c_{i,0}) + E_0 u'(c_{i,1}, x_A) \pi_{B,1} = 0. \tag{7}$$

The first order conditions (4)–(7) have the standard form, i.e. they equate the marginal disutility of saving to the expected marginal utility of the financial investment. Lacking the negative externality, it is easy to see how to reformulate the first order conditions.

Production and profit at time 1 for a generic firm k, $k = A, B$, are described by

$$y_{k,1} = \Gamma_k \times f(x_{k,0}), \tag{8}$$

$$x_{k,0} = x_{i,k,0} + x_{j,k,0}, \tag{9}$$

$$\pi_{k,1} = y_{k,1} - r_{k,1} x_{k,0}, \tag{10}$$

where it is assumed that the production shows decreasing returns to scale. Production therefore is obtained by direct use of the loans made by the investors, but is subject to an exogenous shock which is firm-specific, Γ_k, as shown by (8). Following Brock (1982), it is assumed that the shock is known to the firm when making decisions about the input of resources. Profit, as shown by Eq. (10), is what remains to the firm after paying the loan and the interest to the consumers. Profit is completely redistributed to shareholders in period 1.

What is the difference between loans and stocks from the point of view of the investors? Following Brock (1982) we assume that the exogenous shock is unknown to the investors when these decide the size of the loans but it is known to the firm when the interest rate is set. Therefore both financial investments are risky for the investors. The timing of decisions in the model is therefore the following: first agents determine their demand functions for consumption and financial investments in loans and stocks, then firms see the productivity shock and after that determine the demand for loans. Time 1 consumption is finally determined on the basis of the asset holdings and the productivity shocks which affect production and profit.

The first order condition of the firm is described in (11):

$$\Gamma_k \times f'(x_{k,0}) - r_{k,1} = 0, \tag{11}$$

where f' is the marginal product. Remember that the firm knows the value of the productivity shock before deciding the level of production. The firm therefore takes up the amount of loans which is optimal for the realized productivity shock.

2.3. The mechanics of the model

We assume that there are two productivity shocks for each firm so that there are four states of nature at time t. $q_{A,s}$ is the probability of the sth state for firm A, $s = 1,2$; $q_{B,s}$ is the probability of the sth state for firm B, $s = 1,2$; q_s is the probability of the sth aggregate state, $s = 1,2,3,4$. The aggregate states are defined by the combinations of shocks described in Table 1. This structure implies that the four states are equally likely when $q_{A,1} = q_{B,1} = 0.5$ and that there is no correlation across stocks, an assumption which may seem odd given the impression of increased interdependence of stock markets. However such interdependence has increased mainly from the point of view of international financial markets, but in a very unstable fashion. Goetzmann et al. (2001) conduct a long run analysis of global market correlations and find that the values found on average at the end of the 1990's (about 40%) are a fast a strong upward movement from the values prevailing between the 1950's and the 1980's, closer to 10%. Solnik et al. (1996) also report wildly fluctuating correlation coefficients among major stock markets. Finally, Campbell et al. (2001), showing that the average correlation between two stocks in the US market has decreased over time and is currently very close to 0. These results therefore provide a motivation for the analysis of the low correlation case in the model. In order to also analyze the case of high correlation one can assume the following structure of joint probabilities $q_1 = 0.4$, $q_2 = 0.1$, $q_3 = 0.1$, $q_4 = 0.4$, while negative correlation can be described by $q_1 = 0.1$, $q_2 = 0.4$, $q_3 = 0.4$, $q_4 = 0.1$.

At the initial time the investor, given available wealth, make consumption and portfolio choices. The portfolio is potentially composed of four risky assets, two issued by each firms. After the consumption and portfolio decisions are taken the productivity shocks are realized and observed by the firms, which finally demand loans on the market. Equilibrium is characterised by the following equations:

Table 1
Individual and aggregate states

Firm A	Firm B	
	Individual state 1	Individual state 2
	Shock: $1+\varepsilon$ Probability: $q_{B,1}$	Shock: $1-v$ Probability: $q_{B,2}$
Individual state 1 Shock: $1+\varepsilon$ Probability: $q_{A,1}$	Aggregate state 1 Shock: $1+\varepsilon$, $1+\varepsilon$ Probability: $q_1 = q_{A,1} \times q_{B,1}$	Aggregate state 2 Shock: $1+\varepsilon$, $1-v$ Probability: $q_1 = q_{A,1} \times q_{B,2}$
Individual state 2 Shock: $1-v$ Probability: $q_{A,2}$	Aggregate state 3 Shock: $1-v$, $1+\varepsilon$ Probability: $q_3 = q_{A,2} \times q_{B,1}$	Aggregate state 4 Shock: $1-v$, $1-v$ Probability: $q_1 = q_{A,1} \times q_{B,1}$

The table reports the parameters describing the shocks and the probabilities characterizing the individual states for firms A and B, and shows the implications for the shocks and probabilities of the aggregate states.

$$c_{i,0} + c_{j,0} + x_{i,A,0} + x_{i,B,0} + x_{j,A,0} + x_{j,B,0} = W_{A,0} + W_{B,0}, \tag{12}$$

$$z_A^- = z_{i,A,0} + z_{j,A,0}, \tag{13}$$

$$z_B^- = z_{i,B,0} + z_{j,B,0}, \tag{14}$$

$$x_{A,0}^s = x_{i,A,0} + x_{j,A,0}, \quad s = 1,2,3,4, \tag{15}$$

$$x_{B,0}^s = x_{i,B,0} + x_{j,B,0}, \quad s = 1,2,3,4, \tag{16}$$

where $x_{A,0}^s$ and $x_{B,0}^s$ are the amounts of loan taken up by the two firms in state s at time 0.

We have therefore a system of 18 equations to be solved for 18 endogenous variables. The 18 equations are: the supply function of loans on the part of the two agents (2 equations), the demand function for two stocks on the part of the two agents (4 equations), 8 equilibrium equations between loan demand and supply, the 4 demand functions for loans (4 equations). The 18 variables are the 2 stock prices, the 2 interest rates, the 2 demand for loans, the 8 loan supplies, the 4 stock demand.

Notice that this system does not impose any non-negativity constraint on the variables, in particular on the supply of loans and on the demand for stocks on the part of the investors. A negative value for the supply of loan, for example $x_{i,A,0}$, is compatible with the equilibrium as long as $x_{j,A,0}$ is positive and large enough to make the total supply of loan to firm A positive in equilibrium. A small negative loan on the part of consumer i to firm A and a large positive loan on the part of j to the same company in the aggregate is equivalent to a positive loan of the consumers to the firm together with an internal system of loans whereby consumer i borrows resources from consumer i. The interpretation of this case may refer to a sort of internal financial system, where agents can lend resources to each other. The firm of this stylized model therefore both implements production activities and carries out the role of financial intermediary for personal loans.

A similar interpretation occurs in the case of a negative holding of stock. In equilibrium the supply is fixed so the two consumers together have to hold the stocks. However there can be internal contracts between the two consumers according to which one lends resources to the other with a remuneration contingent on the future valuation of the stock.

To model heterogeneity we refer to the financial side of Merton (1987) which assumes that investors are heterogeneous in their information sets about securities. They decide to trade only stocks for which they have information. The model shows how heterogeneous information sets impact stock prices and returns. More precisely it is shown that stocks of firms with smaller investor bases have relatively larger expected returns, and lower prices, than in the comparable complete-information model. Here we assume that one of the two agents decides a priori to finance only one of the two firms in the economy, voluntarily giving up the possibility of diversification offered by investment in the polluting firm. We define agent i as the discriminating investor. In the minimal case he decides not to invest in the stock of firm A,

the firm which is responsible for the externalities in the model. Therefore $z_{i,A,0} = 0$. In the maximal case he also decides not to lend resources to A, $x_{i,A,0} = 0$. In the latter case discrimination is extended simultaneously to both assets. [2] Notice that there is a difference between discriminating with stock and discriminating with loans. In the model the former does not affect production activity but the latter does. This difference reflects the working of the economic system in the short run, lacking rights issues from firms. We will return to this in the conclusions, when commenting possible extensions of the framework.

Investor i therefore exposes herself to a dramatic decrease in the investment opportunity set. By not diversifying, she forces herself to hold a suboptimal portfolio which is concentrated on firm B.

We can use the model to study a few interesting elements. What are the effects of the discrimination carried out by agent i? What are the effects of discriminating against stocks in terms of overall equilibrium? Is it helpful to discriminate against loans? What is the utility loss of the discrimination? What is the utility transfer between agents i and j following unilateral discrimination? What is the damage inflicted to the firm which produces the externality? In order to answer these questions we will numerically solve the model. The presence of heterogeneous agents requires this technique, as in equilibrium the two investors will end up with different portfolios and consumption choices.

3. Results

We have solved numerically the model due to the presence of various asymmetries, a standard procedure in the literature on the equity premium, see for example Heaton and Lucas (1992). The utility functions are of the constant relative risk aversion type, i.e. $(1-\alpha)^{-1}c_{i,0}^{1-\alpha} + \delta(1-\alpha)^{-1}(c_{i,1}e^{-\gamma x_{A,0}})^{1-\alpha}$ for agent i and $(1-\alpha)^{-1}c_{j,0}^{1-\alpha} + \delta(1-\alpha)^{-1}c_{j,1}^{1-\alpha}$ for agent j.

The externality is introduced in such a way to diminish both the total and the marginal utility. The marginal utility of future consumption becomes in fact is $\delta c_{i,1}^{-\alpha}(e^{-\gamma x_{A,0}})^{1-\alpha}$. For example with $\alpha = 0.5$ it is $\delta\sqrt{(e^{-\gamma x_{A,0}})/c_{i,1}}$ so that the marginal utility of consumption with the externality is equal to the marginal utility without the externality multiplied by a number between 0 and 1 depending on the level of production of firm A.

The parameter δ is fixed at 0.9 in all the computations. The parameters α is set equal to 0.5 and alternatively to 4 in order to analyze the impact of risk aversion on the solution. Calibration of the parameter γ is more difficult. We will calibrate the parameter in such a way to control for the total decrease in utility for consumer

[2] This is not unrealistic. In June 2003 nine major banks from seven countries have decided to adopt guidelines (known as "Equator principles") for project finance in emerging markets, requiring the banks to adhere to the IFC (International Finance Corporation) social and environmental rules for sustainable development. This implies that the banks will not provide loans directly to projects where the borrower cannot comply with certain requirements.

i associated with the externality with respect to the baseline case of no externality. For example, we will see in Table 2 that when externalities are ignored and $\alpha = 0.5$, a choice of $\gamma = 1$ is coherent with an 8% reduction of consumption on the part of i while a choice of $\gamma = 0.5$ is associated with a 5% reduction of consumption. Therefore 1 and 0.5 will be the two values considered in the computations. A similar computation will be performed for the other sets of parameters, yielding $\gamma = 0.3$ and 0.6 when risk aversion is high. The production functions assume decreasing returns to scale with a parameter $\beta = 0.4$. In what follows we refer generally to the discriminating behavior as SRI, even though this has to be considered only as an example of the possible application of the model.

To start, we have solved the model assuming no externalities and no SRI (second column of Table 2) and then the case of externality but no SRI for two different values of the parameter γ (columns 3 and 4 of Table 2). In the absence of externality and

Table 2
Calibration for alternative sets of parameters

$z_{i,A,0}$	0.5000	0.4938	0.4883	0.0	0.0	0.0	0.0
$z_{j,A,0}$	0.5000	0.5062	0.5117	1.0	1.0	1.0	1.0
$z_{i,B,0}$	0.5000	0.4938	0.4883	0.7088	0.5736	0.7254	0.7274
$z_{j,B,0}$	0.5000	0.5062	0.5117	0.2912	0.4265	0.2746	0.2726
$c_{i,0}$	0.7644	0.7901	0.8137	0.7909	0.7900	0.7659	0.7649
$c_{j,0}$	0.7644	0.7526	0.7417	0.7521	0.7526	0.7633	0.7643
p_A	0.3533	0.3429	0.3334	0.3414	0.3427	0.3508	0.3525
p_B	0.3533	0.3429	0.3334	0.3441	0.3430	0.3555	0.3537
$x_{i,A,0}$	0.1178	0.1072	0.0974	0.0	0.1788	0.0	0.0
$x_{j,A,0}$	0.1178	0.1215	0.1248	0.2276	0.0499	0.2339	0.2350
$x_{i,B,0}$	0.1178	0.1072	0.0974	0.3079	0.1773	0.3294	0.3309
$x_{j,B,0}$	0.1178	0.1215	0.1248	−0.0785	0.0513	−0.0924	−0.0951
$y_{A,1}$	0.6169	0.6096	0.6028	0.6085	0.6096	0.6152	0.6164
$y_{A,2}$	0.5048	0.4988	0.4932	0.4979	0.4988	0.5033	0.5043
$y_{B,1}$	0.6169	0.6096	0.6028	0.6104	0.6096	0.6184	0.6172
$y_{B,2}$	0.5048	0.4988	0.4932	0.4994	0.4988	0.5060	0.5050
$\pi_{A,1}$	0.3702	0.3658	0.3617	0.3651	0.3657	0.3691	0.3698
$\pi_{A,2}$	0.3028	0.2992	0.2959	0.2987	0.2944	0.3020	0.3026
$\pi_{B,1}$	0.3702	0.3658	0.3617	0.3663	0.3657	0.3710	0.3703
$\pi_{B,2}$	0.3028	0.2992	0.2959	0.2997	0.2944	0.3036	0.3030
u_i	3.0958	2.9525	2.9564	2.9510	2.9522	3.0923	3.0943
u_j	3.0958	3.0960	3.0965	3.0967	3.0961	3.0976	3.0956

The table reports equilibrium prices and quantities for various sets of parameters. Column 1 contains the variables: $z_{m,n,0}$ is the demand for stocks on the part of the mth agent ($m = 1, 2$) for shares issued by the nth firm ($n = A, B$) at time 0; $c_{m,0}$ is initial consumption on the part of the mth agent; p_n is the price of the stock issued by the nth firm; $x_{m,n,0}$ is the loan from the mth agent to the nth firm; $y_{n,s}$ is production of the nth firm in the sth state of nature ($s = 1, 2$); $\pi_{n,s}$ is total profit of the nth firm in the sth state; u_m is total expected utility of the mth agent. Column 2 refers to the baseline case of no externality and no SRI. Column 3 considers the case of low externality $\gamma = 0.5$ and no SRI. Column 4 the case of high externality $\gamma = 1$ and no SRI. Column 5 the case of low externality and total SRI. Column 6 the case of low externality and partial SRI. Column 7 the case of negative correlation between states of nature and column 8 the case of positive correlation between states of nature.

SRI the equilibrium is symmetric. Each consumer holds 1/2 of the available stock, and the market prices of the stock are equal. Loans are equal. Production, profit and the interest rates are constant across firms even though they vary across states of nature. Consumers have the same utility level.

Introduction of a small externality (with no SRI) affects the equilibrium because the optimal choices of consumer i are affected due to non-separability between the externality and consumption. Consumer i decreases the demand for the stock of the polluting firm and gives less loans to the same firm, however he also varies the demand for assets associated with the non-polluting firm. This can be explained on the basis of the first order conditions of consumer i: the presence of externalities reduces the future marginal utility of consumption, which provides an incentive to increase immediate consumption, to provide less loans and to invest less in the stock market. In equilibrium however the supply of stocks has to be held, so that the price of stocks go down and consumer j increases his demand.

Consumer j also reacts to the change in prices by decreasing initial consumption, partially undoing the decreased saving of consumer i. Utility of consumer i decreases. Production and profit of both firms decrease due to the incentive to consume a larger portion of the initially available resources.

An increase in the importance of the externalities magnifies these effects. [3]

The main interest of the paper is in the general equilibrium effects of SRI. We therefore now analyze the case of responsible behavior of agent i for $\gamma = 0.5$ (the case $\gamma = 1$ is qualitatively similar and the results are not reported). Total SRI means discrimination against both stocks and loans (column 5) while partial SRI only involves stocks (column 6).

The results show that SRI has important effects on personal portfolios. Consumer j ends up being the owner of the polluting firm, with a strong reduction in the stockholding of firm B and a much more concentrated stock portfolio, while consumer i strongly increases the ownership of firm B. There are similar patterns for the loans given to the two firms, which are also part of the SRI behavior. In equilibrium the price of stock A is now lower than the price of stock B, as predicted by the model by Merton in the case of asymmetric demand. Total utility decreases strongly for consumer i and increases for consumer j. The most relevant result is that there are weak price effects on the market prices of both stocks. Consumers substitute each other in stockholdings. There are weak effects on production and profits and a severe utility punishment for the active investor.

Partial SRI is much less disruptive to the overall equilibrium. Consumer i increases loans to firm A as a substitute for the decline in stockholdings. Stock prices are almost the same as the levels holding without SRI. These results show the impor-

[3] The analysis of the high risk aversion case (whose results are available upon request from the author but are not reported for reasons of space), conducted with $\alpha = 4$, are qualitatively similar except that there are lower transfers of resources between one period and the other. This is not surprising as this model, contrary to the more general class of models introduced by Epstein and Zin (1989), is unable to distinguish between risk aversion and elasticity of intertemporal substitution. In the model used in this paper a higher risk aversion therefore also means lower willingness to substitute consumption over time.

tance of financial markets in establishing the effectiveness of an SRI strategy. Active investors should try to affect the behavior of the lending institutions in order to make their discriminating behavior with respect to stocks truly effective.

In other unreported results we have experimented with the relative wealth of the two consumers. A change in the distribution of initial wealth has the expected consequences on the solution. Relative utilities move in the same direction as relative wealth, and the price of stock of firm A is more severely affected by discrimination the larger the share of initial wealth going to the socially responsible investor.

Finally, we study the effects of the varying degrees of correlation among the four states of nature by experimenting with the joint probability distribution. We consider one case where the states with shocks which are simultaneously positive or negative have lower probabilities than the other two states (we call this case "negative correlation"), that is probabilities of 0.1, 0.4, 0.4 and 0.1 for the four states and one case where the states with shocks which are simultaneously positive or negative have higher probabilities than the others ("positive correlation"), that is probabilities of 0.4, 0.1, 0.1 and 0.4. These cases are reported in columns 7 and 8 of Table 2. The results confirm that SRI is more painful to the agent when the correlation is negative. One can expect that from the hedging portfolio of the investor, trying to smooth consumption across states of nature. Also the price differential of the two stocks increases in the negative correlation case with respect to the positive correlation case. This is due to the fact that a negative correlation is equivalent to considering the case where stocks are "more different" among themselves than the case of positive correlation. Therefore giving up the possibility of investing in one asset with a negative correlation is more costly in utility terms, because this exclusion increases volatility of consumption across states of nature.

4. Conclusions

We consider a simple two-period general equilibrium model with uncertainty, production, heterogeneous agents and externalities. We study the existence of discrimination against the firms generating a negative externality towards a subset of the consumers. We consider various channels for discrimination, from not lending to not purchasing the stock issued by the firms. The theoretical model merges the models of Merton (1987) and Brock (1982) by considering both a production economy and heterogeneous demand functions for financial assets. It extends both models by adding an externality.

The model is simple but powerful enough to show some strong implications. Perhaps one of the main messages emerging from the results is that discriminating against firms by means of financial markets is not likely to be a major force in shaping the market equilibrium under certain specific conditions. Such conditions involve combinations of the following elements: (i) discrimination restricted to a small subset of the agents, (ii) high substitutability across firms and (iii) existence of many channels of financial communication between firms and investors. Point (i) is shown by

the experiments with varying initial wealth controlled by the two subsets of investors, point (ii) by the experiments with varying correlation among states of nature and point (iii) by the analysis of the use of stocks and loans in the model. Of course the conditions under which discrimination is not powerful are also the conditions under which the cost of financial discrimination is modest.

Of course our results are obtained in the context of a stylized model. Stock market based discrimination is more likely to be relevant whenever companies are heavily dependent on the stock market as a financing instrument. For example companies are crucially dependent on the stock market in the phase of the initial public offering. Also the initial phase of venture capital depends heavily on the possibility to liquidate the investment by means of a public offering. A coalition of socially responsible investors which were able to boycott the IPO of a firm might perhaps be useful to block its expansion, even though it is hard to believe that other non-responsible investors were not willing to finance a profitable business.

On the other hand the model shows how crucial is the lending activity in determining the effectiveness of discrimination. To be truly effective, investors should not only discriminate against stocks but also establish a coalition with the banking sector, trying to coordinate the efforts. This rarely happens. The implication is that active investors should first try to coordinate with financial institutions and then launch a joint effort at discrimination, which could then be truly effective or, alternatively, they should also discriminate the shares of the banks financing the firms responsible for the targeted behavior.

Acknowledgments

I thank Geoffrey Heal for useful conversations on the topic, two anonymous referees for suggestions on a previous version of the paper and Nicola Tosini for excellent research assistance in the numerical solution of the model. Centro di Economia Monetaria e Finanziaria "Paolo Baffi" at Bocconi University, to which the author is grateful, provided financial assistance for this project.

References

Abel, A.B., 2003. The effects of a baby boom on stock prices and capital accumulation in the presence of Social Security. Econometrica 71, 551–578.

Brock, W.A., 1982. Asset prices in a production economy. In: McCall, J.J. (Ed.), The Economics of Information and Uncertainty. University of Chicago Press, Chicago, pp. 1–43.

Campbell, J.Y., Lettau, M., Malkiel, B.G., Xu, Y., 2001. Have individual stocks become more volatile? An empirical exploration of idiosyncratic risk. Journal of Finance 56, 1–43.

Dai, Q., 2000. From equity premium puzzle to expectations puzzle: A general equilibrium production economy with habit formation. Mimeo.

Epstein, L., Zin, S., 1989. Substitution, risk aversion, and the temporal behavior of consumption and asset returns: A theoretical framework. Econometrica 57, 937–968.

Goetzmann, W.N., Li, L., Rouwenhorst, K.G., 2001. Long-term global market correlations, NBER working paper no. 8612.

Heaton, J., Lucas, D., 1992. The effects of incomplete insurance markets and trading costs in a consumption-based asset pricing model. Journal of Economic Dynamics and Control 16, 601–620.
Jermann, U., Quadrini, V., 2002. Stock market boom and the productivity gains of the 1990s. Mimeo.
Lucas, R.E., 1978. Asset prices in an exchange economy. Econometrica 46, 1429–1445.
Lucas, R.E., 1982. Interest rates and currency prices in a two-country world. Journal of Monetary Economics 10, 335–359.
Merton, R.C., 1987. A simple model of capital market equilibrium with incomplete information. Journal of Finance 42, 483–510.
Naik, V., 1994. Asset prices in dynamic production economies with time-varying risk. Review of Financial Studies 7, 781–801.
Solnik, B., Boucrelle, C., Le Fur, Y., 1996. International market correlation and volatility. Financial Analysts Journal (September/October), 17–34.