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Journal of Pension Economics and Finance / Volume 4 / Issue 01 / March 2005, pp 7 - 16

DOI: 10.1017/S1474747205001939, Published online: 09 May 2005

Link to this article: http://journals.cambridge.org/abstract_S1474747205001939

How to cite this article:

BERTHOLD U. WIGGER (2005). Public pensions and the role of real versus financial capital. Journal of Pension Economics and Finance, 4, pp 7-16 doi:10.1017/S1474747205001939

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Public pensions and the role of real versus financial capital

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Abstract

The paper introduces an unfunded public pension program into an overlapping generations framework recently proposed by Magill and Quinzii (2003). The crucial distinction of the Magill and Quinzii framework is that the financial value of a firm may be lower than the replacement value of its capital. The present paper shows that in this framework unfunded public pensions negatively affect the financial value of firms but have no effect on real capital accumulation and welfare.

1 Introduction

In the Diamond (1965) overlapping generations economy public pensions discourage private savings as the latter are motivated by the desire to secure old-age consumption. The negative effect on private savings will result in reduced aggregate investment if public pensions are of the pay-as-you-go type, i.e. if they are not funded by a capital stock. Reduced aggregate investment, in turn, will lead to lower long-run welfare if the economy evolves on a dynamically efficient path, i.e. if aggregate investment is below the golden rule level.

In the Diamond economy there is a homogeneous output, which can be used for consumption as well as investment purposes. In particular, output, which at first has been invested in the capital stock, can be transformed back into consumption without incurring any costs. This has significant implications for the effects of a public pension policy. Consider the introduction of an unfunded public pension program into a Diamond economy. The working part of the population (the young) will be charged a contribution, which is transferred in the form of a public pension benefit to the retired sector of the population (the old). As a quid pro quo the young will receive a pension benefit when they are old, which will be financed by contributions from the then young. As a consequence of the introduction of the program, the current young will reduce their savings. On the one hand, private savings are less important to secure

* For helpful comments I am grateful to two anonymous referees and the editor Michael Orszag.

old-age consumption as public pension benefits will be forthcoming. On the other hand, contributions to the public pension program reduce disposable income and, thus, the source for private savings. Reduced private savings, in turn, means that the young are less willing to purchase capital goods. However, this has no impact on the well-being of the current old who are the owners of the economy's capital stock and who want to consume their wealth. This is because rather than selling their capital to the young the current old simply transform their capital into consumption goods and eat them up.

Recently, Magill and Quinzii (2003) have modified the Diamond economy by assuming that capital once installed in a firm cannot be transformed back into consumption nor can it be used for new investment in any other firm. Rather, it is a sunk cost. Firms are separate legal entities whose ownership is transferred through the sale of equity in the stock market. Because capital, once installed in a firm, is sunk, the firm's financial capital as evaluated in the stock market can differ from the replacement cost of its real capital. Magill and Quinzii show that in a market equilibrium the equity price of a firm is given by its replacement cost minus a lump-sum discount. The discount is either zero at each time or it is positive and grows at a rate equal to the economy's interest rate. In the first case the market equilibrium resembles the one obtained in the Diamond economy. In the second case, however, the economy converges to the golden rule equilibrium. Magill and Quinzii demonstrate that if the market equilibrium with a zero discount implies aggregate investment below the golden rule level then the zero discount equilibrium is unstable, whereas the positive discount equilibrium is locally stable. Thus, the latter is the natural candidate for comparative dynamic analysis.

The present paper introduces an unfunded public pension program into the Magill–Quinzii framework. It demonstrates that such a program will lower the financial value of capital, but will have no impact on long-run aggregate investment and welfare if the financial value of capital differs from its replacement cost, i.e. if there is a positive discount on real capital. As in the Diamond economy the public pension program will reduce savings of the young. This is compatible with the observed negative relationship between social security and private savings in empirical studies.¹ However, as the financial value of capital decreases, private savings, although reduced, still suffice to perpetuate the level of capital accumulation obtained in the absence of a public pension program. As a consequence, the pension program has no real impact on the economy in the long-run equilibrium.

Subsequently, the paper considers the short-run effects of introducing a public pension program. The paper shows that even in the short run a public pension program may have no real impact. The paper considers a scenario in which the discount on real capital instantaneously adjusts so that the old in the introductory period lose in terms of the financial value of their capital what they gain in terms of pension benefits. The paper demonstrates that such a scenario is consistent with the conditions of a market equilibrium.

¹ See, e.g., Feldstein (1977).

2 The model

2.1 Individuals

The population consists of overlapping generations of the Samuelson (1958)–Diamond (1965) type. At each time t a new generation of N_t individuals is born. The population grows at the constant rate $n \geq 0$, implying that N_t equals $(1+n)N_{t-1}$. Individuals within a generation are identical and live for two periods. In their first period of life individuals inelastically supply one unit of labor in the labor market, contribute part of their labor income to a public pension program, consume another part, and save the remainder for old age. In their second period of life individuals retire and live on the proceeds of their savings and a public pension benefit.

Lifetime utility of a representative member of the generation born at time t , denoted as generation t , is given by $u_t = u(c_t^y, c_{t+1}^o)$, where c_t^y and c_{t+1}^o are the amounts of young- and old-age consumption and u is a utility function satisfying the standard differentiability, monotonicity, and concavity assumptions. Young- and old-age consumption of a member of generation t are constrained by

$$\begin{aligned} c_t^y &= (1-\tau)w_t - s_t, \\ c_{t+1}^o &= (1+r_{t+1})s_t + \pi_{t+1} \end{aligned}$$

where w_t and s_t are the wage rate and savings at time t , r_{t+1} is the interest rate on savings from t to $t+1$, π_{t+1} is the public pension benefit at time $t+1$, and τ denotes the public pension contribution rate, i.e. the relative share of labor income that each young individual has to contribute to the public pension system. By assumption the contribution rate is time invariant.

Each individual chooses those amounts of young- and old-age consumption which satisfy the following first-order condition for maximum utility

$$-u_{1,t} + (1+r_{t+1})u_{2,t} = 0$$

where $u_{i,t}$ is the partial derivative of u with respect to its i th argument at (c_t^y, c_{t+1}^o) . The first-order condition implicitly defines a savings function of the form

$$s_t = s[(1-\tau)w_t, \pi_{t+1}, r_{t+1}] \quad (1)$$

The partial derivatives of the savings function are given by

$$s_{1,t} = \frac{1}{D_t} [u_{11,t} - (1+r_{t+1})u_{12,t}], \quad (2)$$

$$s_{2,t} = \frac{1}{D_t} [u_{12,t} - (1+r_{t+1})u_{22,t}], \quad (3)$$

$$s_{3,t} = \frac{1}{D_t} [s_t u_{12,t} - u_{2,t} - (1+r_{t+1})s_t u_{22,t}] \quad (4)$$

where $D_t = u_{11,t} - 2(1+r_{t+1})u_{12,t} + (1+r_{t+1})u_{22,t}^2$ is the second derivative of the left-hand side of the first-order condition for maximum utility with respect to s_t and, henceforth, negative.

2.2 Public pension program

Public pension benefits are financed according to the pay-as-you-go principle. Wage earners pay the fraction τ of their labor income to a public pension board which, in turn, distributes its revenues to the retirees. At each time t the budget of the public pension program balances so that $N_{t-1}\pi_t = N_t\tau w_t$ or

$$\pi_t = (1+n)\tau w_t \quad (5)$$

respectively.

2.3 Firms

At time t the representative firm is endowed with the capital stock K_t , which it has inherited from time $t-1$ and hires labor L_t in a competitive labor market. It produces a homogeneous good which can either be consumed or invested in new capital. Production of the homogeneous good at time t is determined by $Y_t = F(K_t, L_t)$, where F is a neoclassical constant returns to scale production function satisfying the standard differentiability, monotonicity, and concavity assumptions. Profit maximization implies that the firm hires labor up to the point where the marginal product of labor equals the wage rate prevailing in the labor market. Since the labor market is competitive, the wage rate is market clearing so that the labor force, consisting of the young generation, is fully employed, i.e. $L_t = N_t$ for all t . Let w_t denote the wage rate at time t . It then follows that

$$w_t = F_L(K_t, N_t) \quad (6)$$

where F_L is the partial derivative of F with respect to L . During the production process the firm's capital stock depreciates at the rate β . On the other hand, the firm's capital stock can be augmented by investing in new capital. Thus, if the firm invests I_t units in new capital at time t , the firm will be endowed with capital amounting to $K_{t+1} = (1-\beta)K_t + I_t$ at time $t+1$. Investment I_t is chosen to maximize the net present value of investment which is given by

$$\begin{aligned} \Pi_t = & -I_t + \frac{1}{1+r_{t+1}} [F(K_{t+1}, N_{t+1}) \\ & - w_{t+1}N_{t+1} + Q_{t+1}[(1-\beta)K_{t+1}]] \end{aligned} \quad (7)$$

where $Q_{t+1}[(1-\beta)K_{t+1}]$ denotes the market price which current owners of the firm will receive from the sale of the firm at time $t+1$. At this point the essential difference between the Diamond (1965) and the Magill and Quinzii (2003) framework comes into play. Magill and Quinzii assume that capital which has been installed in a firm cannot be transformed into consumption nor can it be used for new investment in any other firm. Therefore, the market price for a firm can be below its replacement cost

without creating any arbitrage opportunities, since owners of the firm cannot sell their capital for new investment in any other firm or simply use it for consumption as in the standard Diamond (1965) model. Rather than depending on the replacement cost, the price buyers are willing to pay for a firm depends on their expectations concerning the price for installed capital prevailing in the future. Magill and Quinzii (2003) show that the affine price formula

$$Q_{t+1}[(1-\beta)K_{t+1}] = (1-\beta)K_{t+1} - V_{t+1} \quad (8)$$

is consistent with a competitive equilibrium with positive investment in new capital in each period. Here, V_{t+1} is a discount on already installed capital. For $V_{t+1}=0$ at all dates the market price of the firm equals its replacement cost as in the standard Diamond (1965) model. However, if $V_{t+1}>0$, the price of the firm is less than its replacement cost.

A positive discount obtains like a self-fulfilling prophecy. If buyers of a firm expect that they can only sell their capital at a discount in the next period, they will only accept to buy installed capital at a discount today. However, in a competitive equilibrium the sequence of discounts $\{V_t\}_{t=0}^{\infty}$ must satisfy some consistency requirements. First of all, the price for the firm cannot exceed its replacement cost as buyers can always replace the firm by purchasing $(1-\beta)K_{t+1}$ units of current output. Thus, the price for the firm at time $t+1$ must satisfy $Q_{t+1}[(1-\beta)K_{t+1}] \leq (1-\beta)K_{t+1}$ which, in light of equation (8), leads to $V_{t+1} \geq 0$. Second, as sellers of the firm can always abandon their capital rather than selling it at a negative price, it follows that $Q_{t+1}[(1-\beta)K_{t+1}] \geq 0$, which implies $V_{t+1} \leq (1-\beta)K_{t+1}$. Since $(1-\beta)K_{t+1} = (1-\beta)^2 K_t + (1-\beta)I_t$, positive investment at each time t requires that $V_{t+1} \leq (1-\beta)^2 K_t$. To summarize, the sequence of discounts is constrained by

$$0 \leq V_{t+1} \leq (1-\beta)^2 K_t \quad (9)$$

In order to ensure non-arbitrage in the capital market, the sequence of discounts must satisfy a further condition. Buyers purchasing the firm at time t and investing I_t in the firm incur costs amounting to $Q_t + I_t = (1-\beta)K_t - V_t + I_t = K_{t+1} - V_t$. At time $t+1$ the firm yields a dividend of $F(K_{t+1}, N_{t+1}) - w_{t+1}N_{t+1} = (r_{t+1} + \beta)K_{t+1}$ and can be sold at the price $Q_{t+1} = (1-\beta)K_{t+1} - V_{t+1}$. The gross return of the firm from time t to $t+1$ is then given by $[(1+r_{t+1})K_{t+1} - V_{t+1}]/(K_{t+1} - V_t)$. Non-arbitrage requires that the gross return of the firm equals the gross return in the capital market given by $1 + r_{t+1}$. This requires that the discount on installed capital evolves according to

$$V_{t+1} = (1 + r_{t+1})V_t \quad (10)$$

From the single investor's perspective, the discount V_{t+1} is a constant. Therefore, after substituting (8) into (7), it follows that profit maximization requires

$$r_{t+1} = F_K(K_{t+1}, N_{t+1}) - \beta \quad (11)$$

if there is positive investment in the competitive equilibrium.

2.4 Capital market equilibrium

The capital market clears when aggregate savings of the young equal the market value of the representative firm, plus the new investment in the firm. More precisely, capital market clearing requires that $N_t s_t = Q_t + I_t$ for all t . Considering that $K_{t+1} = (1 - \beta)K_t + I_t$ and using (8), the capital market clearing condition becomes

$$N_t s_t = K_{t+1} - V_t \quad (12)$$

3 Equilibrium analysis

The savings equation (1), the public pension budget constraint (5), the factor returns conditions (6) and (11), the non-arbitrage condition (10), the capital market clearing condition (12), and the consistency condition concerning the discount on installed capital (9) implicitly define a competitive equilibrium of an economy with unfunded social security in which capital, once installed, cannot be transformed into consumption. In order to analyze the competitive equilibrium it is convenient to substitute for s_t and π_{t+1} using equations (1) and (2) and to express the equilibrium conditions in intensive form as

$$w_t = w(k_t) = f(k_t) - k_t f'(k_t), \quad (13)$$

$$r_{t+1} = r(k_{t+1}) = f'(k_{t+1}) - \beta, \quad (14)$$

$$0 \leq (1+n)v_{t+1} \leq (1-\beta)^2 k_t, \quad (15)$$

$$(1+n)v_{t+1} = (1+r_{t+1})v_t, \quad (16)$$

$$(1+n)k_{t+1} = s[(1-\tau)w_t, (1+n)\tau w_{t+1}, r_{t+1}] + v_t \quad (17)$$

Here, $f(k) = F(k, 1)$ and $k_t = K_t/N_t$ and $v_t = V_t/N_t$ denote the capital stock per worker and the discount on installed capital per worker at time t , respectively. Substituting (13) and (14) into (16) and (17), leads to a system of two first-order difference equations

$$(1+n)k_{t+1} = s[(1-\tau)w(k_t), (1+n)\tau w(k_{t+1}), r(k_{t+1})] + v_t, \quad (18)$$

$$(1+n)v_{t+1} = [1 + r(k_{t+1})]v_t \quad (19)$$

which define the evolution of the capital stock per worker and the discount per worker.

The economy has reached a steady state if the capital stock per worker and the discount per worker remain unchanged in a competitive equilibrium. A steady state solution (k, v) thus satisfies

$$(1+n)k = s[(1-\tau)w(k), (1+n)\tau w(k), r(k)] + v \quad (20)$$

$$(1+n)v = [1 + r(k)]v \quad (21)$$

and the consistency condition

$$0 \leq (1+n)v \leq (1-\beta)^2 k \quad (22)$$

Obviously, there are two possible solutions for a steady state. The first one is given by $v=0$ and $k=\bar{k}$, where $\bar{k}$ is implicitly defined by

$$(1+n)\bar{k} = s[(1-\tau)w(\bar{k}), (1+n)\tau w(\bar{k}), r(\bar{k})] \quad (23)$$

This steady state is a zero discount equilibrium, which resembles the steady state in the standard Diamond economy. The second steady state, however, is a positive discount equilibrium. It is given by $v=v^*>0$ and $k=k^*$, where k^* is implicitly defined by

$$r(k^*) = n \quad (24)$$

which means that a positive discount equilibrium satisfies the golden rule of economic growth.

Which of the two steady states emerges as the long-run outcome essentially depends on whether the zero discount equilibrium $(\bar{k}, 0)$ is characterized by over- or underaccumulation relative to the golden rule level of accumulation. Magill and Quinzii (2003) have shown that under some regularity conditions concerning the utility function u and the production function f the zero discount steady state $(\bar{k}, 0)$ is globally stable if $r(\bar{k}) < n$, whereas the zero discount steady state $(\bar{k}, 0)$ is locally saddlepoint stable and the positive discount steady state (k^*, v^*) is locally stable if $r(\bar{k}) > n$.²

Thus, if $\bar{k}$ as implicitly defined by (23) satisfies $r(\bar{k}) < n$, then for any initial conditions $k_0 > 0$ and $v_0 \geq 0$ the capital stock per worker converges to $\bar{k}$ and the discount per worker converges to 0. In that case the equilibrium is characterized by overaccumulation because the growth rate n exceeds the interest rate r . It is well known that in case of overaccumulation the competitive equilibrium is dynamically inefficient and intergenerational transfers via a public pension scheme based on the pay-as-you-go principle can lead to a Pareto improvement. However, empirical observations suggest that overaccumulation is not an empirical issue – at least in OECD economies.³ If, on the other hand, the zero discount equilibrium is characterized by underaccumulation, it loses its global stability properties. In that case, for any initial conditions $k_0 > 0$ and $v_0 > 0$ the economy converges to a positive discount steady state satisfying the golden rule, whereas it will only converge to a zero discount steady state if $v_0 = 0$, i.e. if the discount is already zero initially.

² Applied to the present framework with a public pension program, these conditions require that:

- (i) the savings function $s = s[(1-\tau)w, (1+n)\tau w, r]$ satisfies $s_1 > 0$, $s_2 < 0$, and $s_3 \geq 0$,
- (ii) the function σ defined by $\sigma(k) = s[(1-\tau)w(k), (1+n)\tau w(k), r(k)]/k$ satisfies $\lim_{k \rightarrow 0^+} \sigma(k) > 1+n$ and $\lim_{k \rightarrow \infty} \sigma(k) = 0$.

(i) implies that first and second period consumption are normal goods and that the substitution effect of a change in the interest rate dominates the income effect if the two effects are of opposite sign. (ii) is a joint assumption on the utility function and the production function. It is satisfied, for instance, if both the utility function and the production function are of the CES type with elasticities of substitution equal to or larger than 1.

³ See Abel *et al.* (1989).

As the effects of a pay-as-you-go public pension scheme in a zero discount equilibrium have been analyzed extensively and as the positive discount equilibrium is likely to obtain if there is no overaccumulation, the following concentrates on the positive discount equilibrium. Thus, it is assumed that $r(\bar{k}) > n$ and $v_0 > 0$. Then, the long-run impact of a pay-as-you-go public pension scheme can be characterized as follows.

Proposition 1. *In a positive discount steady state an increase in the contribution rate to the public pension program by $d\tau$:*

- (i) *leaves the capital stock per worker unchanged;*
- (ii) *increases the discount on installed capital by $dv = w(k^*)d\tau$.*

Proof. (i) Follows from $n = r(k^*)$ in a positive discount steady state, which means that k^* is independent of τ . To prove (ii), differentiate (20) with respect to τ holding k constant at $k = k^*$. This yields

$$\frac{dv}{d\tau} = [s_1 - (1+n)s_2]w(k^*)$$

From (2) and (3) and $n = r(k^*)$ it follows that $s_1 - (1+n)s_2 = 1$ and therefore

$$\frac{dv}{d\tau} = w(k^*) > 0$$

which proves (ii). □

Thus, in a positive discount steady state, public pensions do not exert any real effect on the economy, but only affect the price at which real capital is transferred from the old to the young. When the contribution rate increases by $d\tau$, steady state savings per worker decrease by $ds = [-s_1 + (1+n)s_2]w(k^*)d\tau = -w(k^*)d\tau$. However, as the discount on capital per worker increases by the same amount, reduced savings still suffice to afford the steady state capital stock per worker which obtained before the policy change.

The analysis so far has confined attention to the long-run effect of a public pension program. It remains to be answered which effects arise in the short run. In order to analyze the short-run effects, imagine that there is an unexpected increase in the contribution rate to the public pension program at time t . The specific sequence of events at time t is as follows. First, firms inherit capital K_t and hire labor L_t for production. During the production process capital depreciates at rate β . Second, the government announces that the contribution rate to the public pension program has increased. Third, firms change owners and new owners undertake investment decisions for period $t+1$. If the government had not announced a policy change, the price at which firms change owners at time t would have been $Q_t = (1-\beta)K_t - V_t$. However, because of the policy change there may be a change in the discount by dV_t in which case the price for a firm endowed with $(1-\beta)K_t$ units of capital reads $Q_t = (1-\beta)K_t - (V_t + dV_t)$. The next proposition clarifies to what extent the discount may change and identifies the concomitant effect on the capital stock per worker.

Proposition 2. *Let the economy be in a positive discount steady state at some time t and consider a small and permanent increase in the contribution rate to the public pension scheme by $d\tau$ at that time. Then, a permanent increase in the discount on installed capital per worker by $w(k^*)d\tau$ at time t and no effect on the capital stock per worker is consistent with the conditions of a competitive equilibrium.*

Proof. Differentiate (18) and (19) totally to get

$$(1+n)dk_{t+1} = -s_{1,t}w(k_t)d\tau + (1+n)s_{2,t}[w(k_{t+1})d\tau + \tau w'(k_{t+1})dk_{t+1}] + s_{3,t}r'(k_{t+1})dk_{t+1} + dv_t, \quad (25)$$

$$(1+n)dv_{t+1} = [1+r(k_{t+1})]dv_t + r'(k_{t+1})v_t dk_{t+1} \quad (26)$$

To prove Proposition 2, it is demonstrated that $dk_{t+1}=0$ and $dv_t=dv_{t+1}=w(k^*)d\tau$ solve equations (25) and (26). Since the economy is in a positive discount steady state at time t , it follows that $k_t=k_{t+1}=k^*$ and $n=r(k_{t+1})=r(k^*)$ if $dk_{t+1}=0$. Making use of this and considering that $s_{1,t}-[1+r(k_{t+1})]s_{2,t}=1$, which follows from (2) and (3), (25) reduces to

$$0 = -w(k^*)d\tau + dv_t \quad (27)$$

which holds true for $dv_t=w(k^*)d\tau$. Substituting $dv_t=w(k^*)d\tau$ and $dk_{t+1}=0$ into (26) and considering that $r(k_{t+1})=r(k^*)=n$, it follows that

$$dv_{t+1}=w(k^*)d\tau$$

Finally, note that $d\tau$ has to be sufficiently small so that condition (22) is not violated. $\square$

Proposition 2 states that even in the short run there may be no real but only a financial effect of a change in the public pension program. It should be noted, however, that for this to happen it is essential that the discount v instantaneously adjusts by the rate $w(k^*)dv$ directly after the policy change. Generally, such an adjustment is possible as the discount is not a real but only a virtual magnitude. Moreover, as has been shown, such an adjustment is consistent with rational decision making and rational expectations and, thus, with the conditions of a competitive equilibrium. Nonetheless, there may be other adjustment profiles which then imply real effects on capital accumulation in some transitory periods.

Proposition 2 has an interesting implication concerning the distributional impact of a pay-as-you-go public pension program. In the traditional model without a difference between real and financial capital, the introduction of a pay-as-you-go system at some time t leads to a windfall for the old at time t as they get a pension benefit without having contributed to the program when young. In the present model, in contrast, there is no such a windfall if there is instantaneous adjustment of the discount. Although the old at time t get a pension without having contributed, they do not benefit from the introduction. This is because the discount on the value of the stock of capital they own increases and, as a consequence, what they win in terms

of a pension benefit they lose in terms of a lower price they get for their capital from the young.

4 Concluding remarks

The present paper has highlighted the effect of a pay-as-you-go public pension program on capital accumulation and welfare, emphasizing the role of expectations concerning the price at which installed capital is traded in the stock market. It has considered a model in which the competitive equilibrium is characterized by a difference between the financial value and the replacement value of capital. In such an equilibrium the introduction of a public pension program (or the abolishment of an already existing one) has been shown to exert no real effect on the economy.

The result established in this paper can be related to the discussion on public pension reform. In the neoclassical growth model, abolishment of a pay-as-you-go public pension scheme, while benefiting future generations, will make pensioners in the transition period worse off.⁴ Only if there are preexisting inefficiencies such as dead weight losses due to taxes on labor income or externalities associated with physical or human capital accumulation, can a pay-as-you-go scheme be abolished without worsening pensioners in the transition period.⁵ The result of the present paper, in contrast, implies that abolishment of a pay-as-you-go scheme does not evoke such a distributional conflict between different generations. In the model of the present paper, the loss that the old suffer from abolishing the public pension scheme is completely offset by an increase in the value of the olds' financial assets.

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⁴ See Breyer (1989).

⁵ See, e.g., Breyer and Straub (1993) on the role of dead weight losses and Saint-Paul (1992) and Wigger (1999, 2001) on the role of externalities.