Guns, Latrines, and Land Reform: Dynamic Pigouvian Taxation

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January 2016

Abstract

Dynamically and statically optimal Pigouvian subsidies on durables will differ in a growing economy. For durables with positive externalities, such as sanitation, statically optimal subsidies will typically grow. However, in a dynamic game, governments can most cheaply induce optimal purchasing time by committing to eventually reduce subsidies. If governments cannot commit, there may be multiple, Pareto-ranked equilibria. The presence of multiple subsidizing bodies, including foreign donors, makes commitment more difficult. As a result, consumers may actually delay purchase, rationally anticipating growing subsidies. In the extreme, the benefits of foreign subsidies for durables that create positive externalities may be more than fully offset by such delays in private investment. For durables with negative externalities, such as guns, delays between the announcement and implementation of taxes or regulation may bring forward purchase, potentially causing policymakers who would otherwise prefer such policies to abandon them. Political actors may also be able to shape others policy preferences by changing private expectations. For example, a political party that announces an intent to redistribute land may reduce current owners' investment incentives, thus reducing the benefits of maintaining existing property rights and making land reform more attractive to the median voter.

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1 Introduction

Standard theory suggests that governments may wish to impose Pigouvian subsidies or taxes on goods which create externalities, such as latrines or cars. We argue that dynamically optimal Pigouvian policies for durable goods will differ from statically optimal policies, since expectations over future government subsidies, taxes, and regulatory policy on durables affect consumers' current purchase decisions.

Consider for example, a government of a growing developing country with widespread open defecation choosing subsidies for latrines to reduce disease transmission. Statically optimal Pigouvian subsidies will grow over time as the economy develops, but if the government raises subsidies over time, consumers will have incentives to delay purchases, reducing the benefit of the subsidy. In the extreme, delays in private investment caused by anticipated subsidy growth may dissipate up to 100% of the private benefits of the transfers to the consumer, and if the durable generates positive externalities, these delays could potentially lower welfare in the economy relative to a counterfactual without subsidies.

We consider the dynamic game when not only do consumer decisions depend on anticipated future government policy, but optimal government policy is influenced by consumers' purchase decisions for durables. We show that if the government does not have the ability to commit, there will be multiple Pareto-rankable Markov Perfect Nash Equilibria, including equilibria in which consumers delay purchase, anticipating greater government subsidies in the future. If the government can commit to a future subsidy path, it can eliminate inferior equilibria. Ideally it would commit to first instituting and then withdrawing subsidies, so as to incentivize consumers to adopt the durable good at the socially, rather than privately, optimal date. A government that can commit to a constant subsidy, but not a temporary subsidy, will need to spend more to induce consumers to adopt at the socially optimal date. The problem could potentially be addressed by subsidies on the flow value of durable services or fines for not possessing the durable, but these policies may be difficult to implement.

Government commitment to subsidy paths may be difficult in the presence of multiple subsidy providers, such as NGOs. As outlined above, anticipation of foreign subsidies could reduce welfare by delaying private investment. This provides a potential justification for governments wishing to regulate NGO subsidies for durables, as well as a new potential rationale for the view of many aid sceptics that aid is not only partially dissipated in waste, but could potentially harm the recipient population (although we are not arguing that there is empirical evidence for this theoretical possibility). The problem could be addressed if NGOs subsidize non-durables rather than durables.

The model can be extended to the case in which durables create negative externalities, and to introduce political-economy considerations. For example, from a static perspective, a political party that believes guns create negative externalities would want to introduce Pigouvian taxes or regulations. However, consumers may stockpile guns between the time the party begins campaigning for such a policy and its eventual implementation. In extreme cases, this dynamic force may make the gun control policy counterproductive, leading the government to abandon it altogether. To take another example, a political party that announces an intent to redistribute land as part of a land reform may reduce current owners' incentives to invest in the land, thus reducing the benefits of maintaining existing property rights and making land reform more attractive to other political parties and to the median voter.

2 Setting

2.1 Agents and structure of the game

We consider a game with two types of agent: the individuals who purchase the durable (e.g. a latrine), and the organizations which provide the subsidies or taxes, typically the government. We consider two types of game: one in which the government is able to commit at time 0 to the future path of subsidies or taxes and one in which they are not. When the government is able to commit, at time 0 they decide their path of subsidies $s(t)$ and then the individuals decide each period whether to buy the durable. The game is solved by first solving the individuals' decisions of whether and when to buy the durable, given the subsidy path, and then solving the government's decision on the optimal subsidy level, given the individuals' reaction functions. In reality government might be restricted to a class of functions for $s(t)$, so we also consider two special cases: when governments can only commit to a constant subsidy path, and when they can commit to a path of static Pigouvian subsidies. When the government is not able to commit, the timing of the game is that in each period t the government sets a subsidy $s(t)$ and then individuals decide whether to buy the durable at the subsidized price $p(t)$. We only consider Markov Perfect Nash Equilibria (MPNE) in pure strategies.

2.2 Technology, preferences and the equilibrium path of non-durable consumption

We consider a closed-economy continuous time Ramsey model with exogenous technological progress at rate $g > 0$, discount rate ρ, and homogeneous agents. We assume a standard Cobb-Douglas production function in capital and labor with exogenous rate of technology change g. Utility is quasilinear in services from the durable u_t^I and total spillovers from others' durables, u_t^S, which are proportional to the number of other people using the durable. Consumption in the other goods has constant intertemporal elasticity of substitution θ, so that discounted lifetime utility of an individual is:

$$\int_0^\infty e^{-\rho t}(c_t^{1-\theta}/(1-\theta) + u_t^I + u_t^S)dt$$

All prices in the paper are in units of consumption of other goods. We assume that the value of the services the durable provides, in that unit, grows with consumption growth, which we think is the relevant case for latrines and many other examples of durables which the government might subsidize.

Since we assume perfect credit markets with interest rate r_t, the Euler equation tells us:

$$\frac{\dot{u}'(c_t)}{u'(c_t)} = \rho - r_t$$

Being in the steady state of the Ramsey model, we have that r_t is constant and $r - \rho = \theta g$. Thus:

$$u'(c_t) = u'(c_0)e^{-\theta g t} \tag{1}$$

The initial consumption level will be tied down by the transversality condition so that the NPV of total consumption (durable and not durable) equals the NPV of wealth minus the NPV of net transfers to the government (taxes).

We assume that the government has lexicographic preferences over social welfare and the cost of subsidies, with social welfare being dominant. This is a simplification and an approximation to the case where government can raise funds at low cost. We initially assume that the government can only subsidize or tax the purchase of the durable, for instance because other types of taxes or subsidies may be too costly to implement. In a later section we consider the case when the government has access to a wider variety of tools.

2.3 Durable good

We assume that the durable, once installed, provides constant flow utility u_L and doesn't depreciate. Thus the present discounted utility of the durable is:

$$\int_0^\infty e^{-\rho t} u_L dt = \frac{u_L}{\rho}$$

Durables also provide a total social externality u_S, so that:

$$u_t^S = \gamma(t) u_S$$

where $\gamma(t)$ is the proportion of the population who have the durable at time t. We treat the utility fron non-durables, own durables and others' durables as separable, abstracting from potential complementarity or substitutability.

The durable is always available on the private market, assumed perfectly competitive. It has constant price p, assumed small relative to lifetime wealth and to the capital stock at purchase time, and assuming implicitly that the production technology grows at the same rate, g, as technology in the rest of the economy. Due to growing consumption, eventually everyone will buy the durable. We assume that the government offers a potentially time-varying subsidy $s(t)$ to this price, positive or negative, where $s(t) = 0$ if the government is not offering subsidies at time t. The subsidy is paid for through lump-sun taxation. Define $p(t) = p - s(t)$ as the price at which the agent can buy the durable at time t.

3 Consumer's problem

In the game with commitment, the individual knows the price path $p(t)$ from the start. In the general game without commitment, the individual only has beliefs over the future prices. However in equilibrium, as we consider pure strategy MPNE, these beliefs are correct, and hence we can also treat the consumer's problem as if they know the price path from the start in this case. The individual's optimization problem, where w_0 represents the net present value of his lifetime wealth at time 0, and others purchase the durable at time t', is:[1]

$$
\begin{aligned}
v(w_0) =& max_{(c_s)_{s\geq 0},t} \int_0^\infty e^{-\rho s} u(c_s) ds + \frac{u_L}{\rho} e^{-\rho t} \\
& s.t. \quad \dot{w}(s) = rw(s) - c(s) - p(t)\delta[s=t] - s(t')\delta[s=t']
\end{aligned}
$$

Individual demand for the durable maximizes the (discounted) benefit minus the cost. Suppose that, at t, the individual buys the durable at price $p(t)$. What is the cost of the expenditure in terms of time 0 utility? It reduces net *wealth* at time 0 to $w_0 - e^{-rt}p(t)$. Now, $v'(w_0) = u'(c_0)$, by the envelope theorem. Thus, the loss in *utility* at time 0, from paying $p(t)$ at t, assuming that $e^{-rt}p(t)$ is small enough so that the curvature of v can be ignored, is $e^{-rt}p(t)u'(c_0)$. As for the benefit of the durable, getting it at time t is worth, in terms of time 0 utility, $e^{-\rho t}\frac{u_L}{\rho}$. Therefore, given price path $p(t) = p - s(t)$, individual demand for the durable, $t^*(p(t)_{t\geq 0})$, satisfies:

$$
t^*(p(t)_{t\geq 0}) \quad := \quad argmax_t \frac{e^{-\rho t}}{u'(c_0)} \frac{u_L}{\rho} - e^{-rt}(p - s(t))
$$

Unsubsidized case Consider first the unsubsidized case, where the price is constant at p. In this case the first order condition gives:

$$
\begin{aligned}
& - \frac{u_L e^{-\rho t}}{u'(c_0)} + re^{rt}p = 0 \\
\Rightarrow & u'(c_{t^*(p)}) = \frac{u_L}{pr} \qquad (2)
\end{aligned}
$$

Implying the individually optimal purchase time t^* given by:

$$
t^* := \frac{1}{\theta g} ln \left(\frac{u'(c_0)pr}{u_L} \right) \qquad (3)
$$

One-time subsidy Suppose the durable is offered at a one-time different price at time t. Purchasing at that time gives a change in lifetime utility from infrastructure, at time t, of $\frac{u_L}{\rho}(1 - e^{\rho(t - t*(p))})$. Not purchasing the unsubsidized infrastructure at time $t^*(p)$ also leads to a savings, in units of time t consumption, of $pe^{r(t-t*(p))}$. Thus, denoting by $w_c(t)$ the willingness to pay for the durable at time t rather than at price p at time t^*, $w_c(t)$ is given

[1] The $s(t')\delta[s = t']$ term just reflects the fact that the subsidies are paid for by the population. It does not affect the maximization problem of the individual.

as follows:

$$w_c(t) \;:=\; max\{pe^{r(t-t^*(p))} + \frac{u_L}{\rho u'(c_t)}(1 - e^{\rho(t-t^*(p))}),\ 0\}$$
$$= \; max\{\frac{pr}{\rho}e^{\theta g(t-t^*(p))} - \frac{p\theta g}{\rho}e^{r(t-t^*(p))}, 0\} \tag{4}$$

General subsidy Now consider the case of a general subsidy. If $s(t)$ is continuously differentiable, the equation for individual demand gives the following first order condition for the optimal time to purchase the durable, $t^*(p(t))$:

$$e^{-\theta g t^*(p)}(r(p - s(t^*(p(t)))) + s'(t^*(p(t)))) = \frac{u_L}{u'(c_0)}$$

This first order condition shows that subsidies, $s(t)$, have two (potentially opposing) effects on the optimal time to purchase the durable, $t^*(p(t))$: the optimal timing becomes earlier with the level of the subsidy, but becomes later with the slope of the subsidy.

4 Government's problem

In this section we assume that the externality is positive. Everything follows, with inequalities reversed, for negative externalities. The social planner's problem is the same as the individual's problem, except with a utility flow from infrastructure of $u_L + u_S$ rather than just u_L. Hence the socially optimal time for purchase of the durable, t^*_s, is given by:

$$t^*_S := \frac{1}{\theta g} ln\left(\frac{u'(c_0)pr}{u_L + u_S}\right) \tag{5}$$

4.1 Government can commit

We consider how the government can offer the subsidies to get people to purchase the good at this time t^*_S, with decreasing levels of commitment.

One-time subsidy If the government has full control over the subsidy path, clearly the cheapest way for them to achieve the first best time is to offer a subsidy at the socially optimal time t^*_S, which makes the individual indifferent between taking the subsidized price at t^*_S and the private price p at t^*, and then to remove the subsidy immediately afterwards.

Such a subsidy satisfies $p - s^* = w_c(t_s^*)$, giving:

$$\begin{aligned} s^* &= p - \frac{pr}{\rho} e^{\theta g(t_S^* - t^*(p))} - \frac{p\theta g}{\rho} e^{r(t_S^* - t^*(p))} \\ &= p\left(\frac{u_S}{u_L + u_S} - \frac{\theta g}{\rho}\frac{u_L}{u_L + u_S}(1 - \left(\frac{u_L}{u_L + u_S}\right)^{\rho/\theta g})\right) \end{aligned} \quad (6)$$

Constant subsidy If the government isn't able to commit to a whole price schedule, but only to a constant subsidy, then this subsidy s_c^* is greater than the subsidy with full commitment s^*:

$$\begin{aligned} & t^*(s_c^*) = t_s^* \\ \Rightarrow & \frac{1}{\theta g} ln\left(\frac{u'(c_0)(p - s_c^*)r}{u_L}\right) = \frac{1}{\theta g} ln\left(\frac{u'(c_0)pr}{u_L + u_S}\right) \\ \Rightarrow & s_c^* = \frac{u_S}{u_L + u_S} p \; > \; s^* \end{aligned} \quad (7)$$

4.2 Government cannot commit

If the government is not able to commit upfront, they face a classic commitment problem: individuals know that if they don't buy at time t_S^* then the government will wish to raise its subsidy in the next period, since the monetary value of the externality will have increased. In our model this results in multiple equilibria.

Proposition

The Markov Perfect Nash Equilibria in this case are all subsidy paths $s(t)$ such that:

$$\begin{aligned} s'(t) \leq \tfrac{u_L}{u'(c_t)} - r(p - s(t)) \qquad & \forall t \geq t_S^* \\ p - s(t) \leq w_c(t) \qquad & \forall t \in [t_S^*, t^*) \end{aligned}$$

and such that individuals prefer waiting for $p - s(t_S^*)$ rather than buying at $p - s(t)$ $\forall t < t_S^*$. Such paths have subsidies which are bounded below at t_S^* by the outside option, and first best timing is achieved,[2] but subsidies are not bounded above at t_S^*.

Proof

Strategies comprise a subsidy path $s(t)$ for the government, and a minimal acceptance price

[2]This is because of our simplifying assumption of governments having lexicographic preferences. The more general case of government facing some cost of raising public funds results in a trade-off between optimal timing (and hence less externalities) and less waste through raising public funds. As such first-best timing is not generally achieved.

$p_{min}(t)$ for the agents. Before t_S^*, the government doesn't want the individual to take up. In the subgame after t_S^* , the government wants the individual to take up immediately, whatever the cost. The individual will take up immediately if the $p - s(t)$ falls at rate no faster than g both locally and globally, and if the buying subsidized is better than waiting to buy unsubsidized. Consider a price path such that $p - s(t)$ is falling at the maximal rate, starting at any given $s(t_S^*)$. The best response of an individual facing this path is to wait until t_s^*, and then buy at minimal price $p - s(t)$ in future periods. The subgame perfect best response of the government, to this best response of an individual facing the path, is the path itself.

4.3 Static Pigouvian subsidies

Suppose instead the government follows static Pigouvian subsidies $s_p(t)$, whose value rises over time: $s_p(t) = \frac{u_S}{\rho u'(c_t)}$. The individual demand equation then gives:

$$\begin{aligned} t^*((p - s_p(t))_{t\geq 0}) &= argmax_t \frac{e^{-\rho t}}{u'(c_0)} \frac{u_L}{\rho} - e^{-rt}\left(p - \frac{u_S}{\rho u'(c_t)}\right) \\ &= argmax_t \frac{e^{-\rho t}}{u'(c_0)} \frac{u_L + u_S}{\rho} - e^{-rt} p \end{aligned}$$

This (by design, since the aim of Pigouvian subsidies is to internalize the externality) is the same as the individual optimization problem without subsidies but with private utility flow $u_L + u_S$. Thus:

$$t^*((p - s_p(t))_{t\geq 0}) = t_s^*$$

Hence statically optimal Pigouvian subsidies actually again give the optimal investment time, but result in significantly larger subsidy payments than if the government could commit to a fixed subsidy level:

$$\begin{aligned} s_p^*(t_s^*) &= \frac{u_S}{\rho u'(c_{t_S^*})} \\ &= \frac{pru_S}{\rho(u_L + u_S)} \\ &= \frac{r}{\rho} s_c^* > s_c^* \end{aligned} \tag{8}$$

4.4 NGOs and durables

The previous section assumed an unchanging utility function for the government and a single provider of subsidies. Without commitment the game resulted in the first best timing, although at a higher cost (this is because of our simplifying assumption of lexicographic preferences for the government. Under more standard preferences, the government would trade-off timing against total expenditure, and hence timing may be delayed). Now consider a case where either government preferences over subsidies or their ability to provide them over time may change, for example with the election of a new party, or a new provider of subsidies may arrive at a later date. Then agents may expect the subsidy to rise considerably in the future, causing them to delay purchase of the durable beyond the optimal time t_s^*, with associated loss of welfare.

NGOs often have preferences for subsidizing certain types of good which may differ from those of the government. For example, some NGOs may consider latrines as merit goods and wish to subsidize them heavily. NGOs' preferences may also change over time, as may their presence in a region. When NGO preferences over subsidies are mis-aligned with those of the government, their subsidizing durables may undermine the ability of the government to commit to a subsidy path.

For a simple model of the potential adverse effects of subsidies on durables, suppose that the NGO will arrive at time t_N and then offers constant subsidy s_N. Suppose also that the individually optimal time to buy at the subsidized price, $t^*(p - s_N)$, satisfies $t^*(p - s_N) < t_N$ so that if the individual waits for the subsidy then they will purchase the durable as soon as the subsidy starts. As the price $p - s_N \to w_c(t_N)$, the willingness to pay for the durable at time t_N, (either through s_N decreasing or t_N increasing) all of the individual benefit from the subsidy is dissipated. Further, if $t_N > t^*$, the optimal time to buy the unsubsidized durable, we see that the subsidy actually delays investment in the durable, because of expectations of future rises in the subsidy, and hence worsens externalities and thus overall national welfare, even if the subsidy is financed from abroad.

For a model which introduces uncertainty on when the NGO will arrive, assume that starting from time $t_N < t^*$, the NGO may arrive at hazard rate λ. If it arrives it provides the durable for free. This modifies the individual demand function by effectively adding λ to the interest rate. Thus, if the individual hasn't yet received the durable for free, the optimal time to purchase the durable is given by:

$$t_N^* = \frac{1}{\theta g} ln \left(\frac{u'(c_0)p(r+\lambda)}{u_L} \right) > t^* \tag{9}$$

Clearly when both $t_N \geq t^*$, i.e. there is no possibility of the NGO arriving before when the individual would have bought the unsubsidized durable without the NGO, and the externality u_S becomes large relative to the private benefit u_L, the existence of the NGO decreases social welfare, again without even accounting for the cost of the subsidy. While delays can dissipate up to 100% of the private value of the subsidy, they can more than fully offset the social benefit of the subsidy.

If the government wants to ensure the first best time t_S^*, it still can do so for those who haven't already received the durable for free before then, but since the outside option is improved for the individual the subsidy will need to be higher. If $t_N \geq t_S^*$ total government expenditure on subsidies will definitely be higher than in the case without NGOs.

The problem could be solved by NGOs financing non-durables, but NGOs often prefer subsidizing durables to non-durables, believing the former to be more "sustainable".

4.5 Tools available to government

In the above we assumed that governments could only subsidize or tax goods through the purchase price. This is a reasonable assumption in many cases, for example such subsidies or taxes can often be added at the factory gate or point of sale, rather than going house to house which could be prohibitively expensive. In practice alternative tools for funding may be available and may be more attractive (Ashraf, Glaeser and Ponzetto (2016)). One alternative approach would be to tax or subsidize *not* owning the good. Often such dual policies are equivalent. However, when the government is able to commit to either a future subsidy or fine in the future, if the policy is correctly designed one will require money to pass through governments hands whereas the other will not, particularly appealing in places of high corruption. Namely, the subsidy offered once at the first best time will result in take-up then. The fine, imposed once just after the first best time, will result in take-up just before, with no fines needing to be collected. In practice such fines might be costly to run, and hence not credible.

The government might also have access to a flow subsidy or tax on ownership. While this is equivalent to a stock subsidy or tax at purchase when the stock value is the net present value of future flow values, there are different implications for the ability to commit. Offering the cash value of the social utility flow at all periods results in first best timing and may be simple to commit to. However, in many examples these flows will be small relative to collection costs, in which case such policies are unlikely to be used.

Another policy which may help with commitment, in the case of varying subsidies, is for the government to agree to pay the subsidies retroactively. However, such policies must be credible, since ex-post the government would want to renege on the retroactive payment.

4.6 Decentralized government spending

While we have so far focused on the affect of expectations on private behavior, the same mechanism can impact the public investment decisions. Namely, if local public infrastructure investments can be made at any time by local government, but may be subsidized in the future by national governments, then local government may forgo investment at the optimal time in order to wait for investment from the national government. As above these delays can dissipate all the local surplus from the national government spending, and in the case of negative externalities, e.g. with poorly maintained highways, the national funding may actually reduce welfare. Again this suggests a role for early commitment by the national government to the future subsidies they will provide and under what conditions.

5 Extensions to other settings

5.1 Guns

We now consider a case in which there is a durable with a negative externality which the government would like to tax, but there is a delay between the announcement the intention to implement the policy and its actual implementation. Such delays are likely in practice, since changes to law take time, and political parties layout their policies in manifestos before coming to power.

The announcement of the policy will increases sales in the short term, contrary to the aims of the government and worsening the social externality. If the time gap is sufficiently long, then as in the example given above in the section on NGOs, introducing the policy may actually reduce welfare. If the government is to introduce tax T at time t, announcing this at time 0, the policy would reduce social welfare if the optimal time to buy a gun is later than t, $t^* > t$, and the gain from buying a gun just before the tax is introduced is greater than that from buying a gun at the optimal time once the tax is introduced:

$$\frac{u_L}{\rho u'(c_t)} - p \geq \left(\frac{u_L}{\rho u'(c_{t^*(p+T)})} - (p+T) \right) e^{-r(t^*(p+T)-t)}$$

The Obama administration may be facing this problem. Gun sales spiked to their highest level in two decades after the Sandy Hook shootings. The Washington Post, following a similar spike after the San Bernadino shootings, wrote “This matches a pattern we’ve seen plenty of times in the past: tragedy, followed by calls for gun control, followed by surging firearm sales. (Ingraham (2016)). While in this case depreciation of guns, constraints in the short term supply of guns, and credit constraints are likely to be much more important factors than consumption growth, space constraints mean we do not develop a new model for this setting. If a per-period tax on ownership of guns is available, as seems potentially realistic in this case, then the problem goes away. Similarly, the problem also goes away if the government is able to announce a tax which will be applied retroactively from the announcement date.

5.2 Land reform

Until now we have considered cases where expectations over future changes in optimal government policy act against the government’s wishes. However, it is possible that the announcement of a future policy change could be self-fulfilling, by making the status quo less attractive. Take the example of land reform and consider a basic model of electoral competition. The main economic justification for private land holdings is that they encourage optimal investment in the land. However, these investments are conditional on beliefs of future ownership. Suppose a pro land reform party announces that, if elected, they will enact extensive land reform. If they have a chance of being elected, this reduces the expected returns to investments in land by land owners, and hence in turn reduces such investments. However, these investments were the justification for not having land reform, and so the marginal voter shifts towards being positive towards land reform and hence so too does the other party, if it is marginal. This makes both land reform and potentially also the election of the pro land reform party more likely.

6 Conclusion

Expectations over the government’s future subsidies, taxes, and regulatory policy on durables, such as latrines or guns, affect consumers’ current purchase decisions. In turn, consumers’ purchase decisions affect optimal policy for future government. We study the resulting dynamic game in a growing economy, arguing that dynamically optimal Pigouvian subsidies and taxes on durables will in general differ from their statically optimal levels. Governments seeking to encourage purchase of a particular durable may wish to commit to eventually reducing subsidies so as to advance consumers' optimal purchase time. If that is impossible, they may wish to commit to a constant level of subsidies. In their original paper on the benefit of governments committing to rules, Kydland and Prescott (1977), Kydland and Prescott give a somewhat related example in which, without a rule prohibiting it, individuals build on floodplains in the anticipation that ex-post the government will build costly flood defenses.

The existence of multiple sources of subsidy, such as multiple layers of government, and especially in developing country settings, foreign donors and NGOs, may make commitment more difficult. We show that in the extreme case, delays in private investment due to anticipated foreign NGO support may dissipate up to 100% of the private benefits of the transfers, and that if the durable generates positive externalities (e.g., latrines in a setting in which open defecation is common), anticipation of future foreign aid could potentially lower welfare in the home economy. This implies that it may be better for NGOs to subsidize non-durables rather than durables, and provides a potential justification for governments wishing to regulate NGO subsidies for durables.

Anticipated future taxes or regulation, for example, on guns, may encourage current consumption, and if there are delays between announcement and implementation, this effect may be great enough to cause a government which would otherwise prefer taxes or regulation to abandon such a policy. Finally, we discuss political economy implications, noting, for example, that if a political party announces an intent to redistribute land, this may weaken private investment incentives, strengthening the case for land reform.

In a related paper, Kremer and Willis (2016), we consider the case in which infrastructure services can be provided through multiple technologies with different economies of scale. For example, in developing country settings, electricity can be supplied either publicly through the grid or privately through off-grid solar, water can be supplied through municipal systems or wells, and waste can be disposed of through a sewage system or through latrines. We consider a context in which consumers have heterogeneous wealth which lead to differences in individual optimal times to invest in infrastructure. In the absence of commitment, there may be multiple equilibria, including equilibria in which the rich expect that the government will not provide infrastructure, and therefore invest early in private infrastructure, in turn reducing incentives for the government to invest in infrastructure. To eliminate such potentially welfare-reducing equilibria, the government may wish to commit to install public infrastructure at a specified future time, and if it lacks the ability to do so, it may wish to tax private infrastructure or build public infrastructure early. We show that greater inequality and slower growth both reduce the desirability of public infrastructure, and identify the circumstances in which segregation by wealth is more or less likely to emerge. Optimal policy also depends on the financing options available to the government: imperfect price discrimination may result in a hold-up problem and the use of other second best policies to raise revenue for the investment. We also consider the case when public and private investments are complements (for example, government investments in roads in a particular area may complement private investments in constructing apartment blocks or office buildings).

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Appendix: Consumer problem and production side

The consumer faces interest rate r, has initial wealth plus net present value of future income w_0, and chooses both consumption path $(c_s)_{s\geq 0}$ and when to purchase infrastructure, t. Their problem is thus:

$$\begin{aligned} v(w_0) = \quad & max_{(c_s)_{s\geq 0},t} \quad \int_0^\infty e^{-\rho s} u(c_s) ds + \frac{u_L}{\rho} e^{-\rho t} \\ & s.t. \qquad \dot{w}(s) = rw(s) - c(s) - p(t)\delta[s=t] \\ & \qquad\qquad w_0 = \int_0^\infty e^{-rs} c_s ds + p(t) e^{-rt} \end{aligned}$$

We can also add in the production side. Firms maximize profits:

$$\pi(t) = F(K, A(t)L) - W(t)L - r(t)K(t)$$

Where F is a constant returns to scale production function, $A(t) = A(0)e^{gt}$ is technology, $W(t)$ is the wage, L is the population, and $K(t)$ is capital. Define $k(t) = K(t)/A(t)L$ and $f(k) = F(k, 1)$, then firms rent capital until $f'(k(t)) = r(t)$. Ignoring infrastructure investment for the moment, this results in the dynamic system:

$$\begin{aligned} \frac{\dot{c}(t)}{c(t)} &= \frac{f'(k(t)) - \rho}{\theta} \\ \dot{k}(t) &= f(k(t)) - c(t)/A(t) - gk(t) \end{aligned}$$

We assume we are in the steady state of this system, in which $\frac{\dot{c}(t)}{c(t)} = g$ and $\dot{k}(t) = 0$. We assume that capital can be freely transformed into the durable. Strictly the durable purchase means that we are not in the steady state of the Ramsey model, since there will be a negative shock to capital at the time of investment in the durable. This shock will result in variation of the interest rate around it, and an anticipatory build-up of capital. However, we make the simplifying assumption that p is sufficiently small compared to $K(t)$ that we can assume that $F_K(K(t), A(t)L) \approx F_K(K(t) - p(t), A(t)L)$, and so that we can ignore variation in the interest rate and assume that we are in the steady state of the Ramsey model.

Returning to the consumption problem, we know, because of the constant interest rate, that $c_s = c_0 e^{gs}$. Suppose the individual faces price path $p(s)$ and decides to buy at time t, while others buy at time t' and the subsidy is paid for by lump-sum taxation. Then, we have:

$$\begin{aligned} w_0 &= \int_0^\infty c_s e^{-rs} ds + p(t)e^{-rt} + s(t')e^{-rt'} \\ &= c_0 \int_0^\infty e^{(g-r)s} ds + p(t)e^{-rt} + s(t')e^{-rt'} \\ &= c_0/(r-g) + p(t)e^{-rt} + s(t')e^{-rt'} \\ \Rightarrow c_0 &= (r-g)(w_0 - p(t)e^{-rt} - s(t')e^{-rt'}) \end{aligned}$$

In a symmetric equilibrium, this will result in:

$$c_0 = (r-g)(w_0 - pe^{-rt})$$

Thus, assuming the individual follows the optimal consumption path, they face the following maximization problem:

$$\begin{aligned} & max_t \int u((r-g)(w_0 - p(t)e^{-rt} - s(t')e^{-rt'})e^{gs})e^{-\rho s} ds + \frac{u_L}{\rho} e^{-\rho t} \\ =& max_t \; ((r-g)(w_0 - p(t)e^{-rt} - s(t')e^{-rt'}))^{1-\theta} \int e^{((1-\theta)g-\rho)s}/(1-\theta) ds + \frac{u_L}{\rho} e^{-\rho t} \\ =& max_t \; -\frac{((r-g)(w_0 - p(t)e^{-rt} - s(t')e^{-rt'}))^{1-\theta}}{((1-\theta)g-\rho)(1-\theta)} + \frac{u_L}{\rho} e^{-\rho t} \\ =& max_t \; \frac{(w_0 - p(t)e^{-rt} - s(t')e^{-rt'}))^{1-\theta}}{(1-\theta)} + \frac{u_L}{\rho} e^{-\rho t} \end{aligned}$$

This gives the first order condition:

$$\begin{aligned} (w_0 - p(t)e^{-rt} - s(t')e^{-rt'})^{-\theta}(rp(t)e^{-rt} - p'(t)e^{-rt}) - u_L e^{-\rho t} = 0 \\ \Rightarrow u'(c_0)(rp(t)e^{-rt} - p'(t)e^{-rt}) = u_L e^{-\rho t} \end{aligned}$$

Which is the same FOC arrived at in the main text using the envelope condition.