How Secondary Markets Undermine Social Responsibility*

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Abstract

We model and analyze secondary markets for durable goods when primary-market production causes negative externalities and secondary-market trade is driven by consumers' social responsibility. Secondary markets may benefit society by allowing responsible consumers to take used goods that would otherwise be discarded, but they also introduce three harmful forces. First, the possibility of buying used goods and thereby causing less harm can raise the demand of responsible consumers, often increasing the production necessary to serve the market. Second, said demand can raise the price of used goods, encouraging purchases of new goods. Third, the possibility of selling used goods and thereby lowering primary purchases by others can make new goods less aversive to responsible consumers, again encouraging new purchases. These forces imply that if used goods have positive private consumption utility, then secondary markets *always* raise production and lower welfare. If used products may have significantly negative private consumption utility, then secondary markets can raise or lower welfare.

Keywords: socially responsible consumers, climate change, externalities, secondary markets, durable goods, used goods

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1 Introduction

Secondary markets for consumer durables have always been active, and they are now touted as increasingly important for reducing environmentally harmful new production. For example, McKinsey predicts that as businesses shift toward sustainable practices, the EU market for recycled, refurbished, and used consumer goods will rise to €400-650 billion (22-38% of the total consumer-goods market) by 2030.[1] Intuition suggests that secondary markets contribute to sustainability efforts in part by engaging socially responsible consumers — consumers who aim to reduce the externalities they cause — to buy products less responsible individuals no longer want. Indeed, sustainability is one main motive consumers cite for purchasing used products or participating in the sharing economy (Guiot and Roux 2010, Turunen and Leipämaa-Leskinen 2015, Edbring et al. 2016, Hamari et al. 2016, Styvén and Mariani 2020, Rodrigues et al. 2023). The perspective that secondary markets are environmentally friendly also emanates from the marketing of intermediaries specializing in these markets.[2] Yet the interaction between social responsibility and secondary markets has not been formally explored in the literature.

In this paper, we investigate the effects of secondary markets when primary-market production causes negative externalities and secondary-market trade is driven by social responsibility. We consider rational consequentialist consumers, who understand and care about their actual impact, naive consequentialist consumers, who do not think through equilibrium effects, and deontological consumers, who only care about their action or direct effect. We formalize the motives of these consumers, define the resulting competitive equilibrium, develop techniques to study it, and identify outcomes and welfare implications.

We find that *as a result of* socially responsible consumers, secondary markets often or typically raise production of externality-generating goods, and thus lower social welfare.

[1] See Gatzer et al. (2022). Recently, the global market for second-hand apparel was estimated at $211 billion (2023, https://www.statista.com/topics/5161/apparel-and-footwear-resale-in-the-us/#topicOverview), and the EU market for second-hand electronics at $79 billion (2022, https://www.transparencymarketresearch.com/europe-secondhand-electronic-products-market.html).

[2] For instance, consider second-hand clothing retailers. ThredUp claims to do "good for people and the planet" (https://www.thredup.com/about). Poshmark wants to make "shopping and selling simple, social, and sustainable" (https://poshmark.com). And Vinted emphasizes that second-hand is "better for you and the climate" (https://company.vinted.com/sustainability). All accessed May 5, 2024.

They do so by introducing three forces that can undermine, and in some examples even reverse, social responsibility. First, by providing a purchase option that is perceived as less harmful, secondary markets raise the demand of responsible consumers, and because somebody must supply the used products, this often raises new production. Second, the preceding demand can increase the price of used goods, increasing the primary demand of consumers who sell on the secondary market. Third, responsible consumers who sell on the secondary market may understand that doing so lowers primary purchases by others, further encouraging purchases of new goods. Nevertheless, responsible consumers can increase welfare when they accept donations of products that would otherwise be discarded. Even then, however, a welfare improvement from the availability of such a trade is not guaranteed.

We begin in Section 2 by introducing our model of markets with rational consequentialist consumers. In each period, consumers can buy new goods at a fixed price P, thus causing a production externality, and trade used goods at a market-determined price p_u, thereby not generating a direct externality. Between periods, a portion of all goods breaks, and the new goods that survive become used. Used goods are substitutes for new goods in private consumption utility, but with marginal utility that is l lower. To these standard ingredients, we add social responsibility by building on Kaufmann et al. (2024). Namely, a consumer derives disutility in proportion $k \geq 0$ to the rise in production she causes through her purchases, both directly and through her (infinitesimal) effect on prices. This impact depends on the behavior of other consumers, and is hence endogenously determined. To isolate implications of trade due to social responsibility, we assume that consumers have the same consumption utility, but may differ in their "social coefficients" k. We look for steady-state equilibria in which consumers take deviations from the steady-state p_u as one-time.

In Section 3, we illustrate some key insights in two examples where consumers are either selfish ($k = 0$) or socially responsible with the same $k = \kappa > 0$. We first consider situations in which the private distaste l for used goods is quite substantial ($P < l < P + \kappa$). This might, for instance, apply to low-quality fast fashion and similar merchandise one sees at traditional thrift stores. In the absence of a secondary market, selfish consumers discard their used goods each period, and buy new goods instead. Responsible consumers, in contrast, keep used goods and buy new goods only to replenish their stock. When a secondary market exists, there may be an equilibrium in which selfish consumers “sell” — or, rather, donate — some of their used goods at a price of zero to responsible consumers, who forego new goods to avoid generating an externality. The secondary market thereby reduces new production and waste, and improves welfare.

For our second example, we posit that used goods are not privately unpalatable ($l = 0$). This might, for instance, apply to higher-quality apparel, whose resale markets have grown tremendously in the last few years. Then, an equilibrium may arise in which the used price p_u is relatively high, and in each period selfish types buy new goods and sell all of their used goods to socially responsible types. Due to the separation of consumers, buying used goods does not generate an externality — it just lowers the consumption of other used-goods buyers. The lack of an externality impact liberates responsible consumers, while a high resale price p_u encourages selfish consumers, to purchase more than without a secondary market. Hence, the secondary market raises new production, the ultimate source of all consumption, and thereby lowers welfare. This result provides a new explanation for why sellers may favor secondary markets, and suggests that promoting resale can even serve as a seemingly responsible, but actually harmful greenwashing strategy.

In Section 4, we show that our second example is robust: when used goods have positive private consumption value ($l = 0$), secondary markets are always harmful. To start, we investigate outcomes for a general continuous distribution of social coefficients k. Unlike in our examples, a consumer may then affect production in all future periods, so her impact on total production is unclear. To obtain traction on the problem, we reformulate our equilibrium conditions in terms of the contemporaneous “cross-market effect” of a used purchase on production. Using this result, we establish that the secondary market always weakly raises everyone’s consumption and production. In particular, (i) there is always an equilibrium in which outcomes are as without the secondary market; and (ii) there is often also an equilibrium in which everyone’s consumption and production are *strictly* greater than without the secondary market.

In addition, we study the effects of naive or deontological consumers, who believe that buying a new good is harmful or morally wrong, while buying a used good is not. Noting that these two types behave identically, we describe our results in terms of naive consumers.

With a population of only naive consumers, a bad equilibrium similar to case (ii) above obtains for any distribution of social coefficients k. Moreover, market interaction between rational and naive consumers introduces further welfare-decreasing effects. To isolate these, we assume that all consumers have the same $k = \kappa > 0$, with a share α being naive, and a share $1 - \alpha$ being rational. If α is relatively low, then naive consumers are encouraged to buy used goods by the low used price p_u. And if α is relatively high, then rational consumers are doubly encouraged to sell used, and thus buy new, goods: first to obtain a high resale price p_u and second to lower naive consumers' new purchases. In either case, production is higher than without the secondary market; in the latter case, it can even be *increasing* in the production externality and κ.

Section 5 illustrates that our first example is not robust: when used products can have negative consumption utility, secondary markets may or may not be beneficial. We begin by returning to the setting of our example. If the share of socially responsible consumers is low, the unique equilibrium is the one we have identified previously. For a higher share of responsible consumers, however, the used price rises above zero, encouraging selfish consumers to buy more new goods. Consequently, the welfare effect of the secondary market is now ambiguous. And if the share of responsible consumers is high, the secondary market encourages free-riding in responsible behavior among them. This can lead to equilibrium non-existence or to the secondary market being harmful again. Finally, we identify harmful effects in a system of rationed donations. The knowledge that her donations will reduce new purchases by others encourages a responsible consumer to buy more new goods, while the availability of free goods encourages a recipient to consume more used goods.

Overall, our results suggest that secondary markets often weaken or eliminate the benefits of social responsibility, and vice versa. This implies that if one is expecting a large contribution from social responsibility, then secondary markets are a shaky addition to sustainability policy. Even so, our results do not imply that secondary markets are generally harmful — they can be beneficial if trade on them is driven by reasons other than social responsibility.

We conclude in Section 6 by highlighting several areas for future research, including the effects of recycling, different forms of consumer naivete, the endogenous determination of product durability, and socially responsible consumers' efforts to alter the beliefs of firms.

Related literature Our paper contributes primarily to the theoretical analysis of social responsibility among consumers and to the understanding of durable goods and secondary markets. To the best of our knowledge, we are the first to combine these topics, as well as the first to analyze the effects of responsible consumers in a dynamic product market.

For modeling markets with socially responsible consumers, we build on the static framework of Kaufmann et al. (2024), but our dynamic setting leads to different theoretical challenges and economic mechanisms.[3] In much of the other research on the market effects of socially responsible consumers and investors (Sobel, 2007, Dufwenberg et al., 2011, Pastor et al., 2021, Piccolo et al., 2022, Aghion et al., 2023, Arnold, 2023, Dewatripont and Tirole, 2024), a person's social concern depends exogenously on actions or outcomes, whereas in our setting it depends on the consumer's endogenous equilibrium impact. Furthermore, papers that do consider impact-based social preferences (e.g., Norwood and Lusk, 2011, Moisson, 2020, Green and Roth, 2021, Hakenes and Schliephake, 2021, Broccardo et al., 2022, Herweg and Schmidt, 2022, Krahnen et al., 2023, Trammell, 2023, Oehmke and Opp, forthcoming) study questions and use methods that are different from ours.

There is also an extensive body of classical theory on durable goods and secondary markets. This literature investigates questions such as the choice of durability by firms (e.g., Swan, 1970), time inconsistency (e.g., Coase, 1972), planned obsolescence (e.g., Bulow, 1982), and monopolists' incentives to interfere with secondary markets (e.g., Hendel and Lizzeri, 1999, 2002), but does not consider markets with socially responsible consumers.

On the empirical side, there is substantial evidence for the type of consumer we analyze. Many studies, including incentivized experiments by Rodemeier (2023), Meier et al. (2023), Schulze Tilling (2024), and Andre et al. (forthcoming), show that consumers care about their externality effects. The importance of social concerns in the purchase of second-hand goods is also well-documented in the literatures on sustainability (e.g., Borusiak et al., 2020, Varah et al., 2021, Rodrigues et al., 2023) and the sharing economy (e.g., Hamari et al., 2016).

[3] In fact, by assuming that new products are available in fully elastic supply, we abstract from the main effect on which Kaufmann et al.'s predictions rely, "dampening". Dampening means that when a consumer raises her consumption, she raises the market price and thus induces others to consume less, lowering the externality she brings about. This static effect does not appear to interact with the dynamic issues due to durability and secondary markets that we investigate in this paper.

2 Framework

We consider an infinite-period economy with markets for new and used goods each period. New goods are available in perfectly elastic supply at price P, and their sale raises externality-generating production one-to-one. Used goods are available at a market-determined price, and their trade does not generate direct externalities. If in one period a person consumes amounts $c_n \geq 0$ and $c_u \geq 0$ of the new and used goods, respectively, then she starts the next period with an amount $(1-f)(c_n + c_u)$ of used goods, where $f \in (0,1)$. This means that between periods, a share f of all products breaks, and new goods become used goods. There is also free disposal, so that the used price must be non-negative.

We define a *steady-state competitive equilibrium* as a situation satisfying five conditions. The first three pertain to outcomes and expectations: (i) there is a constant used price $p_u^* \geq 0$ as well as constant consumption; (ii) p_u^* balances the secondary market, i.e., the market features either $p_u^* = 0$ and excess supply or market clearing in each period; and (iii) within an arbitrarily small neighborhood, a consumer takes a surprise deviation in the used price from p_u^* as idiosyncratic, expecting a return to p_u^* in the future.

The fourth condition defines individual behavior: a consumer observes the current used price $p_u \geq 0$, and chooses consumption amounts $c_n \geq 0$ and $c_u \geq 0$ to maximize

$$U_k(c_n, c_u) = u(c_n + c_u) - lc_u - Pc_n - p_u c_u + p_u^*(1-f)(c_n + c_u) - k \cdot (c_n r_n^* + c_u r_u^*). \quad (1)$$

The first two terms represent gross consumption utility, with $l \geq 0$ capturing a distaste for used goods. The function $u(\cdot)$ is twice continuously differentiable, with $\lim_{c \to 0} u'(c) = \infty$, $u''(c) < 0$ for all $c \geq 0$, and $\lim_{c \to \infty} u'(c) = 0$. The next two terms are the payments for c_n and c_u, and the fifth is the expected secondary-market value of used goods next period. To these elements of standard private utility, the last term adds social concerns. A consumer's concern is proportional to her social coefficient k, which is distributed in the population according to the cumulative distribution function G. Furthermore, the consumer's concern derives from her equilibrium impact $c_n r_n^* + c_u r_u^*$ on total production over time, where r_n^* and r_u^* denote the impacts of new and used purchases, respectively.

Crucially, as the fifth condition for equilibrium, we impose a consistency requirement on r_n^* and r_u^* by adapting Kaufmann et al.'s (2024) static framework to our setting. This applies in the limit when each consumer is vanishingly small, i.e., the number of consumers approaches infinity. Intuitively, the impacts r_n^* and r_u^* arise because a consumer's purchases shift the demand curve, which can have both direct and indirect effects on market-clearing production. By assumption, buying a new good has a direct, one-to-one effect on current production. Buying a used good can have an indirect effect on current production by raising the used price p_u and thereby inducing others to buy new. And any new production caused by either purchase can have indirect effects on future production by raising the future supply of used goods and thereby lowering future used prices. Kaufmann et al. show that while a vanishingly small consumer's effect on prices is negligible, her indirect effect on quantities through prices is typically not. Furthermore, there is mutual interdependence between a consumer's effect and the demand curve: the latter derives from consumer choices given the former, and due to the indirect effects, the former depends on the latter.

Formally, r_n^* and r_u^* are consistent if all of the following hold. (a) The consumer's objective (1) has a maximum for each k on the support of G. This implies that in combination with G, consumer optimization generates a per-period per-person gross demand curve

$$(D_n(p_u), D_u(p_u)) = E_G\left[\arg\max_{c_n, c_u} U_k(c_n, c_u)\right].$$

(b) For a shift in the *current* curve to $(\Delta_n + D_n(p_u), \Delta_u + D_u(p_u))$, the current market-balancing p_u and production are unique in a neighborhood of the equilibrium values $\Delta_n = \Delta_u = 0$ and steady-state level of gross used supply, and at the equilibrium values they are differentiable in Δ_n and Δ_u.[4] Any change in production also changes future used supply, whose effect equals minus the effect of a shock to used demand. Recursively, therefore, differentiability of the contemporaneous effects implies that production in each future period is also differentiable in Δ_n and Δ_u. (c) The intertemporal sums of the derivatives of production with respect to Δ_n and Δ_u exist, and equal r_n^* and r_u^*, respectively.

Corresponding to the previous intuitive requirements, (a) determines equilibrium demand taking the effects r_n^* and r_u^* as given. (b) models the effects of purchases that are vanishingly small relative to the market through small shifts in demand (and requires the effects to be

[4] The above uniqueness and differentiability hold whenever the market-balancing p_u and production are fully determined by market forces, i.e., when either $p_u^* > 0$, or $p_u^* = 0$ and almost all consumers have a strict preference between the products. Alternative requirements for the case of $p_u^* = 0$ and indifference yield qualitatively identical results.

well-defined). In Appendix B, we present and modify part of Kaufmann et al.'s analysis to motivate such a definition of a consumer's impact. Finally, given (b), the sums in (c) equal the production effects of a small consumer's purchases per unit, which under consistent expectations must equal r_n^* and r_u^*.

Several comments are in order. First, the anchored belief imposed by condition (iii) is plausible because noise in price determination (which we do not model but is present in reality) makes small deviations from equilibrium undetectable. Second, U_k does not include the consumer's used goods from before. Since these do not affect available consumption choices or their ranking, they do not affect current optimal behavior. Third, U_k is defined over current consumption only. Due to the separability of current optimal behavior from past consumption just noted, maximizing intertemporal utility with discount factor δ approaching 1 is in the limit equivalent to maximizing U_k. We use our simpler formulation to avoid carrying around δ. Fourth, all consumers have the same consumption-utility function. If consumers had different inherent tastes, there may be trade on the secondary market for purely private reasons. We abstract from this classical force to isolate effects due to social responsibility. Fifth, our specification implicitly imposes that upon deviation from equilibrium, a consumer still expects to have the equilibrium impacts r_n^* and r_u^*. Such an assumption is natural for consumers with anchored beliefs and a vanishingly small price impact.[5]

We will compare outcomes with a secondary market to those without one. In the latter case, a consumer's steady-state consumption c_n^*, c_u^* solves

$$(c_n^*, c_u^*) = \underset{c_n, c_u : c_u \leq (1-f)(c_n^* + c_u^*)}{\arg\max} u(c_n + c_u) - lc_u - Pc_n + p_u^*(k)(1-f)(c_n + c_u) - k \cdot c_n. \qquad (2)$$

The absence of trade in used goods introduces three differences relative to (1): the term $-p_u c_u$ is absent, there are no indirect effects of consumption ($r_n^* = 1$, $r_u^* = 0$), and used consumption c_u is bounded by the amount of used goods available from before. Further, we impose that used goods have a shadow value of $p_u^*(k) = \max\{P + k - l, 0\}$ in the next period.

[5] Note also that in our model, buying a new good raises production much like made-to-order manufacturing does. In reality, consumers buy previously produced goods from retailers, raising the question of how this is different from buying used goods. A simple modification clarifies. Suppose that small retailers order from producers at the beginning of each period, and sell to consumers afterwards. Each retailer has concave utility from the amount of leftover products at the end of the period. This captures, in reduced form, the incentives of retailers to keep a stockpile to cover demand shocks. Then, a consumer understands that if she consumes more, the retailer's stockpile decreases, so the retailer will order more next period to restock. Hence, consumers treat a retailer that obtains its ware directly from the producer as a make-to-order producer.

The first argument reflects that having a used good, rather than buying a new one, saves $P + k$ in financial and social-concern costs, but lowers utility by l. The second argument reflects free disposal. Introducing a shadow value to account for these considerations is necessary because (2) is again defined over current consumption only. The same shadow value would emerge in the alternative specification with discounting discussed earlier.

We assume that production has an exogenously given externality cost of $K > 0$ per unit.[6] Accordingly, we define steady-state social welfare as per-period total gross consumption utility minus $P + K$ times per-period production. Moreover, we posit that $k < K$ and $l < P + K$. The first inequality means that no consumer fully internalizes the social cost of the externality she causes. The second inequality implies that disposing of used goods and instead buying new goods is socially inefficient, i.e., it creates "premature waste."

For interpreting results, it is useful to distinguish premature waste from "unavoidable waste," which cannot be consumed in a socially beneficial way ($l > P+K$). In our framework, the proportion f of goods that breaks each period can be thought of as unavoidable waste. The extent to which real-life waste is premature or unavoidable is unclear, so the existence of waste is consistent with all versions of our model below.

3 Simple Examples

In this section, we present some key mechanisms through examples in which the distribution of k is binary: a share g of consumers is selfish ($k = 0$), and a share $1 - g$ is socially responsible with $k = \kappa > 0$. As one practical illustration, we use apparel markets; other potential applications include electronics, furniture, books, and sports or outdoor equipment.

3.1 Reducing Premature Waste: Beneficial Secondary "Market"

First, we provide our best case for secondary markets in the presence of socially responsible consumers. To do so, we assume that l satisfies $P < l < P + \kappa$.

[6] We focus on production externalities, but any externalities from related waste (e.g., environmental degradation from landfilling unwanted textiles) can be included in K. Since all new production eventually becomes waste, in steady state the two must equal in quantity.

Benchmark 1: no secondary market Since $l > P$, selfish consumers prefer new goods for all of their consumption each period, and face the shadow price of zero. This implies that they always toss their used goods from before. Since $l < P + \kappa$, however, responsible consumers strictly prefer used goods they already have to new goods. Nevertheless, they do buy new goods each period to replace broken items.

Benchmark 2: secondary market with only selfish consumers ($g = 1$) Selfish consumers are unwilling to buy in the used market for any $p_u \geq 0$. Hence, we must have $p_u^* = 0$, so that consumers behave as without the secondary market.

Secondary market with socially responsible consumers There may be an equilibrium in which (i) $p_u^* = 0$, $r_n^* = 1$, $r_u^* = 0$; (ii) selfish consumers buy new goods, sell any used goods for which there is demand, and discard the rest of their used goods; and (iii) socially responsible consumers only buy used goods. Consumer behavior is clearly optimal given (i), so we check consistency of the equilibrium impacts r_n^* and r_u^*. If a consumer buys a used good, she just reduces what selfish consumers discard, and does not affect current new production or future market outcomes. Hence, $r_u^* = 0$. If a consumer buys a new good, in contrast, she raises production this period by one unit; she also raises used supply, and consequently waste, next period by $1 - f$ units, but does not affect any other outcomes. Hence, $r_n^* = 1$. Now since selfish types face the same p_u^* as without the secondary market, they consume the same amount. With responsible types shunning new production, therefore, the secondary market lowers total production. Such an equilibrium exists if the share of responsible consumers, g, is sufficiently high for their supply of used goods to exceed the amount responsible consumers need to replace each period.

Intuitively, socially responsible consumers make a private sacrifice to decrease premature waste and thereby lower the need for new production. By facilitating this sacrifice, the secondary market raises welfare. But because $p_u^* = 0$ and market clearing fails, the exchange of used goods is more akin to donation than to market trade.

The above equilibrium is potentially consistent with the reality of apparel donations to thrift stores and other organizations. Anecdotal evidence suggests that little of the donated items is sold at the stores, a lot of it is sold in developing countries, and much of it ends up being downcycled, incinerated, or landfilled (e.g., Cobbing et al., 2022). This could reflect the mix of sales and waste in our model. Another interpretation, however, is that donations often constitute unavoidable waste. In fact, the fast fashion that enters the donation ecosystem is not designed to last, so many items may no longer be socially useful.

3.2 Trading Useful Goods: Harmful Secondary Market

We make a single change to the model: we let $l = 0$. Then, consumption utility depends only on total consumption $c = c_n + c_u$ and equals $u(c)$, so a consumer always values all used goods.[7] It is plausible that much or most of the resale market for used apparel and mobile phones — a sector growing much faster than traditional donation and thrift stores[8] — deals in such more valuable items. Indeed, without the opportunity to resell, brand-name clothing may be worth keeping even if rarely worn, and an old mobile phone may be worth having as a backup.

Benchmark 1: no secondary market Since any marginal consumption comes from purchasing new goods, type $k \in \{0, \kappa\}$ chooses $c_k^{\neg sm}$ to solve $u'(c_k^{\neg sm}) - (P + k) + (1 - f)(P + k) = 0$, or $u'(c_k^{\neg sm}) = f(P + k)$. New production replaces broken goods, so it equals $f(gc_0^{\neg sm} + (1 - g)c_\kappa^{\neg sm})$ in each period.

Benchmark 2: secondary market with only selfish consumers ($g = 1$) Consumers do not care whether a product is new or used, so the two products must trade at the same price ($p_u^* = P$). Hence, consumers choose the same level of consumption, and production is the same, as without the secondary market.

[7] As before, a fraction f of all products breaks between periods. An equivalent formulation arises if all goods survive, but they lose a portion f of their value between periods. Then, denoting the consumption of τ-period-old products by c_τ, consumption utility depends on $c = c_n + \sum_{\tau=1}^{\infty}(1 - f)^\tau c_\tau$. In that case, different vintages will have different, exponentially decreasing prices.

[8] See, for instance, ThreadUp (2024). The US apparel resale sector grew from \$3 billion in 2017 to \$22 billion in 2022, and is expected to reach \$42 billion by 2027. The same numbers for traditional donation and thrift stores are \$17 billion, \$22 billion, and \$28 billion, respectively.

Secondary market with socially responsible consumers There may be an equilibrium in which (i) $P < p_u^* < P + \kappa$, $r_n^* = 1$, $r_u^* = 0$; (ii) selfish consumers strictly prefer to buy new goods and sell all of their used goods each period; and (iii) socially responsible consumers strictly prefer to buy used goods. Consumer behavior is clearly optimal given (i), so we check consistency of r_n^* and r_u^*. If a consumer buys a used good, she raises the used price p_u and induces responsible others to buy less. But due to the strict preferences of both types, this does not affect current new purchases by others or future market outcomes. Hence, $r_u^* = 0$. If a consumer buys a new good, in contrast, she raises current production by one unit. This also raises used supply and thus lowers used prices in future periods, but again due to the strict preferences of consumers, these changes do not affect future new purchases or production. Hence, $r_n^* = 1$.

In the above equilibrium, types $k \in \{0, \kappa\}$ choose consumption levels c_k^* to solve

$$u'(c_0^*) = P - (1-f)p_u^* \quad \text{and} \quad u'(c_\kappa^*) = fp_u^*. \tag{3}$$

Furthermore, the equilibrium exists if g is such that the market-clearing condition $(1 - f)gc_0^* = f(1-g)c_\kappa^*$ holds, i.e., the amount selfish consumers sell equals the amount socially responsible consumers need to replace each period. New production per period is therefore $gc_0^* = fgc_0^* + (1-f)gc_0^* = fgc_0^* + f(1-g)c_\kappa^* = f(gc_0^* + (1-g)c_\kappa^*)$. Now $P < p_u^* < P + \kappa$ implies that $P - (1-f)p_u^* < fP$ and $fp_u^* < f(P+\kappa)$, so $c_0^* > c_0^{\neg sm}$ and $c_\kappa^* > c_\kappa^{\neg sm}$. As a result, production is strictly higher than without a secondary market. Since secondary markets are neutral without but harmful with responsible consumers present, there is a negative interaction between secondary markets and social responsibility.

Intuitively, responsible consumers understand that by buying used goods, they are not generating an externality — they merely crowd out used consumption by others. This liberates them to buy more, driving up the price of used goods. Anticipating a high resale price in turn induces selfish consumers to consume more as well. Importantly, the latter is an equilibrium feedback effect that responsible consumers — unable to influence expectations regarding *future* prices — cannot mitigate by changing their current behavior. Since all purchases ultimately come from new production, the rise in everyone's consumption is harmful for the level of the externality and social welfare.

In some situations, the secondary market not only raises the harm that stems from the externality, but also lowers the population's average private consumption utility net of prices paid. As a notable extreme example, suppose that $p_u^* \approx P + \kappa$. Then, responsible types consume approximately the same amount as without the secondary market, while selfish types consume strictly more. But since $u'(c_0^{\neg sm}) = fP$, the latter increase is in the range where marginal utility is below fP, the per-period price of maintaining a unit of steady-state consumption. Intuitively, the secondary market does nothing but act as a subsidy to selfish types that is inefficient even ignoring externalities.

While we have assumed perfectly elastic supply, a further point emerges with an increasing supply curve. In that case, the secondary market may raise the new price, benefiting sellers.[9] This possibility provides a novel argument for why sellers may like secondary markets, and is consistent with the fast-growing tendency of brand-name apparel makers to embrace resale.[10] Furthermore, our model suggests that the promotion of resale is a greenwashing strategy. Since in equilibrium used goods generate less of an externality than new goods, a firm with a resale program appears to be environmentally friendly. Yet having a secondary market raises new sales and is environmentally unfriendly.

3.3 What Is Missing

In our examples, we have assumed a particular distribution for k, posited that all consumers are rational and consequentialist, and focused on selected equilibria. The rest of the paper expands the analysis. Section 4 shows that for products that are privately valuable even

[9] E.g., suppose that the supply curve is a step function: it equals $P' < P$ up to quantity $q' < gc_0^*$, and P for higher quantities. While this leaves the preceding equilibrium, including the new-good price P, unchanged, q' and P' can be chosen such that the new-good price without a secondary market is $P' < P$. To confirm this, define c_0' and c_κ' as the candidate equilibrium consumption levels without a secondary market and price P'. These satisfy $u'(c_k') = f(P' + k)$ for $k = 0, \kappa$. The equilibrium without a secondary market has price P' if the aggregate quantity $f(gc_0' + (1 - g)c_\kappa')$ is less than q'. We know that this is the case for $P' = P$ and $q' = gc_0^*$. By continuity, the same must be the case for P' and q' close-by.

[10] E.g., ThreadUp (2024), or Bhattarai ("Old clothes, new customers," Washington Post, January 31, 2020). The number of brands with resale programs increased from 4 in 2018 to 163 in 2023. Common intuition and some research (e.g., Rust, 1986, Waldman, 1996) suggests that a secondary market harms sellers by lowering demand for new products. Swan's independence result (Swan, 1970, Sieper and Swan, 1973) implies that a secondary market has no effect on sellers. Other research shows that a secondary market can benefit sellers by allowing them to expand the customer base or price discriminate (e.g., Anderson and Ginsburgh, 1994, Hendel and Lizzeri, 1999).

used ($l = 0$), the insight that secondary markets are harmful is robust to more general assumptions. Section 5 establishes that for products that are privately quite unpalatable ($P < l < P + \kappa$), the insight that secondary markets are beneficial is not robust.

It is also worth noting that we have only considered the cases $l = 0$ and $P < l < P + \kappa$. The economic logic for $l < P$ is similar to that for $l = 0$, but the analysis is more cumbersome. And $l > P+\kappa$ implies that both types of consumers treat the product as if it was non-durable, obviating the dynamic considerations in this paper.

4 Robustness of Harmful Secondary Markets

4.1 Rational Consumers

We modify the model from Section 3.2 (where $l = 0$) by assuming that the distribution G of social coefficients k has support $[\underline{k}, \overline{k}]$ and admits a continuous positive density g. All other assumptions are unchanged. Section 4.1.1 puts our equilibrium conditions in a more convenient form for analysis. This is helpful because the situation is more complicated than in Section 3, where, due to a separation of markets, there are no indirect effects of consumption on production. Section 4.1.2 provides the main result.

4.1.1 Consumer Behavior and Equilibrium

Recall the consistency conditions for the equilibrium impacts of new and used consumption on total production, r_n^* and r_u^*, defined in Section 2. The derivative of *current* production with respect to Δ_n is 1, and we denote the derivative with respect to Δ_u — the contemporaneous cross-market effect of used consumption on production — by Q_c^*; this is also the negative of the derivative with respect to current used supply. We show in the proof of Proposition 2 that if $r_n^* = r_u^*$ and $p_u^* = P$, then consumers are indifferent between new and used products, yielding $Q_c^* = 1$; and otherwise $Q_c^* \in [0, 1)$. In the following, we reformulate our equilibrium conditions in terms of Q_c^*.

Consumer Behavior We first derive r_n^* and r_u^* as a function of Q_c^*, also allowing us to characterize consumer behavior. To do so, we trace out the effect of increasing today's production by one marginal unit on total production over time. This quantity is r_n^*; and since raising current used consumption by a unit raises current production by Q_c^* and affects future production only through this channel, we have $r_u^* = Q_c^* r_n^*$. Now if current production rises by one unit, used supply next period rises by $(1-f)$ units. Hence, production next period decreases by $Q_c^*(1-f)$ units. Adding these effects, next period's consumption rises by $(1-Q_c^*)(1-f)$ units, increasing used supply in two periods by $(1-Q_c^*)(1-f)^2$ units. This lowers production in two periods by $Q_c^*(1-Q_c^*)(1-f)^2$ units. Continuing this logic, the total impact of raising current production by one unit is

$$r_n^* = 1 - Q_c^*(1-f) - Q_c^*(1-Q_c^*)(1-f)^2 - \cdots = \frac{f}{1-(1-f)(1-Q_c^*)}. \tag{4}$$

For notational as well as conceptual reasons, we introduce the policy function $C : \mathbb{R}_{>0} \to \mathbb{R}_{>0}$ that solves $u'(C(e)) = e$ for any $e > 0$. This is the consumption level that a selfish consumer would choose for a non-durable good with price e. We will express consumption in the form $C(e)$, calling e the consumer-specific *effective price* of a unit of instantaneous consumption. Our analysis above implies:

Proposition 1 (Individual Consumer Behavior)**.** *There are effective prices*

$$e_n^k = P-(1-f)p_u^* + k\frac{f}{1-(1-f)(1-Q_c^*)} \quad \textit{and} \quad e_u^k = p_u-(1-f)p_u^* + k\frac{fQ_c^*}{1-(1-f)(1-Q_c^*)}$$

such that (1) if $e_n^k < e_u^k$, then the person strictly prefers new goods, and consumes $c_k = C(e_n^k)$; (2) if $e_n^k > e_u^k$, then she strictly prefers used goods, and consumes $c_k = C(e_u^k)$; and (3) if $e_n^k = e_u^k$, then she is indifferent, and consumes $c_k = C(e_u^k) = C(e_n^k)$ in some combination.

Steady-State Competitive Equilibrium If $r_n^* = r_u^*$ and $p_u^* = P$, then $Q_c^* = 1$, which is consistent with $r_n^* = r_u^* (= f)$. In any other situation, $Q_c^* < 1$, so that $r_n^* > r_u^*$. For such cases, let k' be the unique consumer who is indifferent between new and used products ($e_n^{k'} = e_u^{k'}$):

$$k' = \frac{(p_u - P)(1-(1-f)(1-Q_c^*))}{f(1-Q_c^*)}.$$

By Proposition 1, types $k < k'$ buy new and types $k > k'$ buy used. As a result,

$$D_n(p_u) = \int_{\underline{k}}^{k'} c_k g(k) dk \quad \Rightarrow \quad D_n'(p_u^*) = \frac{1-(1-f)(1-Q_c^*)}{f(1-Q_c^*)} g(k^*) c_{k^*},$$

where k^* is the equilibrium indifferent type. Similarly, noting that $\partial c_k/\partial p_u = 1/u''(c_k)$,

$$D_u'(p_u^*) = -\frac{1-(1-f)(1-Q_c^*)}{f(1-Q_c^*)} g(k^*)c_{k^*} + \int_{k^*}^{\overline{k}} \frac{1}{u''(c_k)} g(k)dk.$$

By market clearing for used goods, we must have $k^* \in (\underline{k}, \overline{k})$, so $D_u'(p_u^*) < 0$. Since the current supply of used products is fixed, we also have that $\Delta_u + D_u(p_u)$ is constant, so that $\partial p_u/\partial \Delta_u = -1/D_u'(p_u^*)$, yielding $Q_c^* = \partial D_n(p_u)/\partial \Delta_u|_{p_u=p_u^*} = D_n'(p_u^*)/(-D_u'(p_u^*))$. Plugging in the above expressions, we conclude that

$$Q_c^* = \frac{(1-(1-f)(1-Q_c^*))g(k^*)c_{k^*}}{(1-(1-f)(1-Q_c^*))g(k^*)c_{k^*} - f(1-Q_c^*)\int_{k^*}^{\overline{k}}(1/u''(c_k))g(k)dk}, \tag{5}$$

and we obtain:

Proposition 2 (Equilibrium Characterization in Terms of Q_c^*)**.** *The following are equivalent.*

I. There is a steady-state competitive equilibrium with the used price $p_u^* \geq 0$, cross-market effect $Q_c^* \in [0,1]$, cutoff type $k^* \in (\underline{k}, \overline{k})$ such that types $k < k^*$ buy new and types $k > k^*$ buy used, and consumption levels c_k for $k \in [\underline{k}, \overline{k}]$ given by Proposition 1 with $p_u = p_u^*$.

II. We have that:

1. *The cross-market effect Q_c^* satisfies Equation (5).*
2. *The type k^* is indifferent: $f(1-Q_c^*)k^* = (p_u^* - P)(1-(1-f)(1-Q_c^*))$.*
3. *The secondary market clears: $(1-f)\int_{\underline{k}}^{k^*} c_k g(k)dk = f\int_{k^*}^{\overline{k}} c_k g(k)dk$.*

Furthermore, any steady-state competitive equilibrium is payoff equivalent (for all consumer types as well as social welfare) to one in I.

4.1.2 The Harm from Secondary Markets

Armed with Proposition 2, we prove the main result of this section:

Proposition 3 (Secondary Markets are Weakly Harmful)**.**

I. There is a steady-state competitive equilibrium in which $p_u^* = P$, $Q_c^* = 1$, and consumers are indifferent between new and used goods. Each consumer's consumption and social welfare are identical to that without the secondary market.

II. In any other steady-state competitive equilibrium, $p_u^* > P$, $Q_c^* < 1$, and almost all consumer type k's consumption is strictly higher, while social welfare is strictly lower, than without the secondary market.

III. The latter type of equilibrium does not exist if $g(k)$ is sufficiently high for all $k \in [\underline{k}, \overline{k}]$. Fixing the other primitives, for any G there is a $\hat{G}$ arbitrarily close in the sup norm such that with k distributed according to $\hat{G}$, the latter type of equilibrium exists.

By Part I, there is always an equilibrium that replicates outcomes without a secondary market. Intuitively, if others are indifferent between new and used products, then the market always equilibrates at equal prices ($p_u^* = P$), so a consumer does not affect others' consumption levels. Since the supply of used products is fixed, buying a unit of either product must therefore raise new production by exactly one unit ($Q_c^* = 1$). This has two implications. First, consistent with equilibrium, the consumer is also indifferent between the products. Second, she has the same incentives as without a secondary market — where any marginal consumption comes from new items — so she consumes the same amount.

Part II says that if any other equilibrium occurs, welfare is lower than without the secondary market. Generalizing the logic of our example in Section 3, a used-good purchase has a less-than-one-to-one effect on production ($Q_c^* < 1$). This fosters consumption by more responsible consumers, pushing up the used price p_u^*. At the same time, less responsible consumers purchase new goods, and are encouraged in doing so by the high level of p_u^*.

Part III states that the second, inferior type of equilibrium does not exist if the distribution G of consumers' social coefficients k is sufficiently dense everywhere, but it always exists for some distributions close to G. If $g(k)$ is large everywhere, a small increase in the used price p_u pushes many consumers toward new goods, yielding a Q_c^* near 1. But with everyone having similar social coefficients and the two products having similar impacts on production, the premium on used products cannot be maintained. Hence, for the inferior equilibrium to exist, $g(k)$ must be sufficiently small at least within a range, for instance due to a bimodal or widely dispersed distribution of k. The range necessary to ensure existence may be arbitrarily narrow.

4.2 Naive Consumers

The model so far assumes rational consumers, who correctly understand their net effect on the externality. This section analyzes the implications of naive consumers, who understand or think about only their direct effect. Thus, a naive consumer believes that buying a new good causes an externality, but buying a used good does not, so she chooses $c_n \geq 0$ and $c_u \geq 0$ to maximize $u(c_n + c_u) - Pc_n - p_u c_u + p_u^*(1-f)(c_n + c_u) - kc_n$. The behavior of naive consumers coincides with that of deontological consumers, who dislike buying new products out of principle in proportion to their social coefficients k. Hence, our analysis applies to deontological consumers as well. Note that with no secondary market, naive consumers have the same belief about new products as rational consumers, so they behave the same way, consuming $C(f(P + k))$.

4.2.1 Only Naive Consumers

We first reconsider the model from Subsection 4.1 with the single modification that all consumers are naive. Since naive consumers have standard preferences defined over their own consumption, a classical definition of competitive equilibrium applies, and standard analytical tools can be used. We obtain:

Proposition 4 (Secondary Markets with Naive Population)**.** *There is a unique steady-state competitive equilibrium. In this equilibrium, $p_u^* > P$, and almost all consumer types k consume strictly more, while welfare is strictly lower, than without the secondary market.*

There is now no equilibrium in which $p_u^* = P$. If this was the case, all socially responsible consumers would prefer used goods, so the market would not clear. Hence, $p_u^* > P$, and a situation akin to that in the bad equilibrium with rational consumers arises. Less responsible consumers buy new goods and sell their used goods on the secondary market, and are encouraged in doing so by the high resale price. More responsible consumers in turn buy used, and because they believe they are not causing an externality, they consume a lot too.

Comparing Propositions 3 and 4, it is immediate that the best equilibrium with rational consumers yields higher welfare than the equilibrium with naive consumers. This is because rational consumers are capable of recognizing the link between the primary and secondary markets. However, we have found that the welfare comparison between a bad equilibrium with rational consumers and the equilibrium with naive consumers is ambiguous.

4.2.2 Mixed Population

We now posit that there are both naive and rational consumers in the market, and denote their shares by α and $1-\alpha$, respectively. To isolate the implications of their interaction, we suppose that everyone has the same social coefficient $k = \kappa > 0$. Analogously to the situation in the rational model, then, $Q_c^* = 1$ if either naive or rational consumers are indifferent between the two products, and $Q_c^* = 0$ if neither type is indifferent. Moreover, it is immediate that the latter case is impossible. If it occurred, then (having the same beliefs) rational and naive consumers would have a strict preference for the same product, violating market clearing. We therefore analyze the former case. Note that since Proposition 1 derives directly from Q_c^*, it applies without modification to the behavior of rational consumers.

Rational consumers are indifferent Since $Q_c^* = 1$ and rational consumers are indifferent, product prices must be equal ($p_u^* = P$). By Proposition 1, a rational type's consumption is then $c_r^* = C(f(P+\kappa))$, as without the secondary market. A naive consumer, however, prefers used goods, and consumes $c_n^* = C(P-(1-f)P) = C(fP)$. Since $fP < f(P+\kappa)$, the secondary market raises her consumption, lowering social welfare. Intuitively, she is encouraged to consume by the availability of cheap used goods, which she believes are harmless.

For this equilibrium to exist, naive demand for used products must be less than the available amount: $\alpha c_n^* < (1-f)(\alpha c_n^* + (1-\alpha)c_r^*)$, or $\alpha f C(fP) < (1-\alpha)(1-f)C(f(P+\kappa))$. Hence, the equilibrium exists if there are sufficiently many rational consumers.

Naive consumers are indifferent For naive consumers to be indifferent, the price of used goods must be $p_u^* = P + \kappa$. Then, whichever product a naive type chooses, her steady-state consumption is $C(f(P+\kappa))$, as without the secondary market. By Proposition 1, rational types strictly prefer new products, and consume $C(fP + (2f-1)\kappa)$. Since $fP + (2f-1)\kappa < f(P+\kappa)$, they consume more than without the secondary market, so that the secondary market lowers social welfare.

Worse, if $f < 1/2$, then $fP + (2f-1)\kappa < fP$, so rational types' consumption is greater than it would be if the product was not polluting, or if all consumers were selfish. Intuitively, rational types are encouraged to consume by two considerations not present without the externality (or with selfish consumers). First, naive consumers push up the price of used products. Second, rational consumers know that when they sell their used goods, they lower new production. For $f < 1/2$, these forces outweigh rational types' concern for the current production externality.

Furthermore, not only rationals' consumption, but total consumption can be higher than when the product is not polluting, or when consumers are selfish. This happens if demand is sufficiently more responsive to effective-price decreases than to effective-price increases from fP. Despite a population with identical social coefficients, therefore, we could have the perverse situation in which production of a good is increasing in the good's production externality and consumers' social responsibility.

For this equilibrium to exist, rational demand for new products must be less than steady-state production: $(1-\alpha)c_r^* < f(\alpha c_n^* + (1-\alpha)c_r^*)$, or $\alpha f C(f(P+\kappa)) > (1-\alpha)(1-f)C(fP + (2f-1)\kappa)$. Hence, the equilibrium exists if there are sufficiently many naive consumers.

Existence Rewriting the two equilibrium existence conditions above gives

$$\frac{\alpha}{1-\alpha} \cdot \frac{f}{1-f} < \underbrace{\frac{C(f(P+\kappa))}{C(fP)}}_{<1} \quad \text{and} \quad \frac{\alpha}{1-\alpha} \cdot \frac{f}{1-f} > \underbrace{\frac{C(fP+(2f-1)\kappa)}{C(f(P+\kappa))}}_{>1}. \tag{6}$$

It is apparent that in an intermediate range of α, neither type of equilibrium exists. The reason is the discontinuity of Q_c^*, which must be either 0 or 1. One way to restore equilibrium is to relax our definition of a consumer's impact when both types have strict preferences between the products, allowing for any $Q_c^* \in [0, 1]$ in this case. Such an assumption can be microfounded by introducing an arbitrarily small exogenous source of other demand that drives the cross-market effect when rational and naive types separate. It is easy to check that with the expanded definition, an equilibrium almost always exists, and the economic logic is unchanged: in any equilibrium, welfare is strictly lower than without the secondary market.[11]

[11] When both types have strict preferences, it must be that rational types prefer new and naive types prefer used, and, using Proposition 1, $P + \kappa > p_u^* > P + \kappa \frac{f(1-Q_c^*)}{1-(1-f)(1-Q_c^*)}$. This implies that both types consume strictly more than without the secondary market. Furthermore, for α such that the inequalities in (6) go strictly the other way, we can choose $Q_c^* = 1$ and a p_u^* to satisfy the market-clearing condition $(1-\alpha)(1-f)C(P-(1-f)p_u^* + f\kappa) = \alpha f C(fp_u^*)$, so that equilibrium exists. A p_u^* satisfying the condition exists because the right-hand side is greater than the left-hand side for $p_u^* = P$ and lower for $p_u^* = P + \kappa$,

The model in this subsubsection extends the static two-good mixed-population model in Kaufmann et al. (2024, Section VII.B) to a dynamic setting in which one good is a used version of the other. When rational consumers are indifferent, the two models generate similar equilibrium logic (whereby naive consumers ignore the cross-market effect and thus overconsume). When naive consumers are indifferent, however, dynamics completely changes outcomes and welfare implications. Furthermore, in both cases the dynamic model is necessary to identify the effects of secondary markets.

5 Fragility of Beneficial Secondary Markets

Section 3.1 suggests that with a substantial private distaste for used goods, secondary markets are beneficial. We now establish that this insight is not robust. Since identifying precise conditions under which secondary markets raise welfare appears intractable, we proceed through examples.

5.1 Secondary Markets and Premature Waste

We first return to the setting of Section 3.1: we assume that all consumers are rational, shares g and $1-g$ have $k=0$ and $k=\kappa$, respectively, and $P<l<P+\kappa$.

Proposition 5. *In any steady-state competitive equilibrium, socially responsible types buy used, and selfish types buy new. Further, we have the following.*

A. [Equilibrium Characterization.] *There are* $\underline{g}, \overline{g}$ *satisfying* $0 \leq \underline{g} < \overline{g} < 1$ *such that:*

I. If $g > \overline{g}$*, then the equilibrium is unique, and has* $p_u^* = 0, Q_c^* = 0$*. Selfish types consume the same amount as without the secondary market, and responsible types consume more. Social welfare is higher than without the secondary market.*

II. If $\underline{g} < g < \overline{g}$*, then the equilibrium is unique, and has* $p_u^* \in (0, P+\kappa-l), Q_c^* = 0$*. Both types consume more than without the secondary market.*

III. If $g < \underline{g}$*, then an equilibrium does not exist.*

and $C(\cdot)$ is continuous. In the corner cases where one of the comparisons in (6) is an equality, equilibrium still does not exist. Then, a consumer's purchases have an asymmetric, non-differentiable effect on the used price p_u.

B. [Fragility of Welfare Gains.] *For any $P, \kappa, l, K, g,$ and f with $f^2(1-g) > g(1-f)$, there is a utility function $u(\cdot)$ such that in the unique equilibrium, total private consumption utility is lower and production is higher than without the secondary market.*

Part A characterizes equilibrium outcomes. If there are few socially responsible consumers (I), the unique equilibrium is the one we have identified in Section 3.1. In this equilibrium, some used goods are donated (i.e., sold at a zero price) to socially responsible consumers, and the rest are discarded. Responsible consumers' willingness to reuse goods that would otherwise be wasted raises welfare.

If socially responsible consumers are more numerous (II), their demand for used products pushes up the used price p_u^*. Part B establishes that as a result, the secondary market can be doubly harmful again, both increasing production and lowering total private consumption utility. To show this, we construct a situation in which the secondary market leads responsible consumers to replace their new purchases with used products, making them privately worse off. To supply these used goods, selfish consumers inefficiently increase their own consumption of new goods. Furthermore, since the goods are quite fragile, satisfying responsible consumers' thirst for used goods requires a large volume of new purchases by selfish consumers. As a result, production is higher than without the secondary market.

Finally, if the share of socially responsible consumers is high (Part A, III), then an equilibrium may not exist. Since responsible consumers have demand that exceeds used supply, in any equilibrium some of them must buy new goods, while others buy used. Then, all responsible consumers strictly prefer to free-ride by buying new and letting others buy used, a contradiction.[12]

Equilibrium does, however, exist under a minor relaxation of our requirements. Recall that the definition of equilibrium in Section 2 requires the reaction to a consumer's purchases to be uniquely determined by preferences and market clearing. This is not satisfied when $p_u^* = 0$ and responsible consumers are indifferent between the two products, ruling out equilibria with these properties. But it is natural to allow other considerations to tie down trade in such situations. As an example, suppose that the group of responsible consumers

[12] Precisely, if responsible consumers bought both new and used goods, they would have to be indifferent between them. Then, an individual would know that new production does not depend on which product she chooses (i.e., $Q_c^* = 1$). Hence, for any $p_u \geq 0$ she strictly prefers new goods, contradicting equilibrium.

first sells a share ρ_s of their used goods and then buys a share ρ_b of the total used goods available for purchase, where ρ_s and ρ_b are equilibrium objects. Then, changing the amount of used goods available to others by a unit through buying or selling changes others' used consumption by ρ_b. As a result, an equilibrium exists for any $g < \underline{g}$, and satisfies $p_u^* = 0$ and $P + \kappa(1 - \rho_b^*) = l$. Intuitively, the free-riding problem above induces responsible types to lower used consumption and thereby reduce the used price to zero as well as waste some used products ($\rho_b^* < 1$). The resulting market slack makes responsible types indifferent between the products, ensuring that at least some used goods are consumed. A simple calculation confirms that if $\rho_s^* > 0$, then the level of production can be higher than without the secondary market.[13] The harmful effect now occurs because the secondary market facilitates free-riding.

5.2 Welfare and Donations

We identify other problems under a system of rationed donations — when p_u is restricted to be zero, and there is excess demand for used goods. This rules out one main welfare-decreasing mechanism we have found, that a high used price encourages new purchases. Beyond theoretical interest, our analysis is also of practical relevance, as some non-profit organizations distributing used goods may make a policy of charging no or minimal prices.

We modify our model in Section 5.1 in the following ways. First, there are rational and naive socially responsible consumers, whose social responsibilities κ_r and κ_n satisfy $l > P+\kappa_r$ and $l < P + \kappa_n$, respectively. The share of naive consumers is α. Second, consumers can donate unwanted items, which others can receive for free. To ration demand, there is an ex-ante known and fixed order in which consumers can ask for donations. Each consumer who gets a turn can replace her broken items, but not take more of the donated goods. The process continues until supplies run out. Third, as a variant of anchored beliefs, consumers encountering a deviation expect the amount of available donations to return to the steady-state level from the next period.[14]

[13] Consider equilibria with $\rho_s^* = 1$. Since $p_u^* = 0$ and responsible types are indifferent between the products, each type's consumption is the same as without the secondary market. Now without the secondary market, a share $1 - g$ of used products is consumed, whereas with a secondary market, a share $\rho_b^* = (P + \kappa - l)/\kappa$ is. The latter can be arbitrarily small.

[14] Formally, we can define the rationing rule in terms of the shadow value of a marginal unit of the used good next period. For any consumer before the steady-state amount of donations is exhausted, the shadow

Benchmark: no donations Since $l > P+\kappa_r$, a rational consumer buys new products each period and disposes of the leftovers in the next period. She thus consumes $C(P+\kappa_r)$. A naive consumer keeps her used products until they break, so she consumes $C(f(P+\kappa_n)+(1-f)l)$. The amount of new production per period is $(1-\alpha)C(P+\kappa_r)+\alpha f C(f(P+\kappa_n)+(1-f)l)$.

Main analysis We look for an equilibrium in which (i) rational consumers donate their used goods; (ii) donations are in short supply; and (iii) naive consumers keep used goods and accept donations if available. In this situation, naive types who can obtain all their replacements for free choose consumption level $C(l)$, while naive types who cannot obtain donations consume as without the secondary market. Further, a marginal increase in a rational type's donations will be given to a naive type who in steady state receives less than her full consumption from donations. As a result, the increase in donations does not affect the recipient's consumption, so it lowers new production one to one.[15] This means that rational consumers' effective price is $P+\kappa_r-(1-f)\kappa_r = P+f\kappa_r$, leading to consumption level $C(P+f\kappa_r)$. The equilibrium exists if the resulting donations are insufficient to satisfy the demand of all naive consumers: $(1-\alpha)(1-f)C(P+f\kappa_r) < \alpha f C(l)$. If the equilibrium exists, new production per period is

$$(1-\alpha)C(P+f\kappa_r)+\left(\alpha-\frac{(1-\alpha)(1-f)C(P+f\kappa_r)}{fC(l)}\right)fC(f(P+\kappa_n)+(1-f)l).$$

The first term is new purchases by rational consumers. The fraction inside the parentheses is the share of consumers who obtain their consumption from donations, so the second term is new purchases by naive consumers who have no access to donations.

value is $p_u^*(k)=\max\{P+k-l,0\}/(1-f)$. This reflects that broken products can be added back to the consumer's stock for free. For other consumers, the shadow value is $p_u^*(k)=\max\{P+k-l,0\}$, as without donations. Our specific assumption about rationing allows us to demonstrate our points in a simple way. In richer models, a variant of a priority order may endogenously arise. For instance, some consumers may be more willing to exert effort to obtain donations due to their income or social responsibility.

[15] For completeness, consider also what happens if a rational consumer lowers her donation. We consider two cases. In case 1, the donation would have been received by a consumer who does not obtain all of her consumption from donations. Then, the effect is the opposite of that above, so the effect on new production is one-to-one. In case 2, the donation would have been received by a consumer who obtains all of her consumption from donations. Because less is available, the recipient cannot replace her broken goods for free. However, she expects to do so again from the next period, as she assumes the steady-state amount of donations will be available. Hence, she chooses the same amount of consumption, buying new goods instead of the donations. As a result, the effect of donations on new production is again one-to-one.

The difference in production relative to a situation without donations is $1-\alpha$ times

$$\underbrace{\left(C(P+f\kappa_r)-C(P+\kappa_r)\right)}_{\text{donor encouragement}}-\underbrace{\frac{C(f(P+\kappa_n)+(1-f)l)}{C(l)}}_{\text{recipient encouragement}}\underbrace{(1-f)C(P+f\kappa_r)}_{\text{avoided waste}}. \tag{7}$$

As in the previous subsection, donations divert unwanted used goods from disposal to use by others, raising welfare. There are, however, two countervailing forces. On the donor side, a socially responsible consumer realizes that she decreases new production through the used goods she makes available. This makes it more acceptable to buy new goods, encouraging consumption. On the recipient side, the availability of donations lowers the financial cost as well as perceived externality of consumption. This again encourages higher consumption, lowering the number of consumers donations can serve. It is clear that both effects can be arbitrarily strong or weak, so that the welfare effect of donations is ambiguous. In particular, if consumption is very price elastic, then $C(P+f\kappa_r) \gg C(P+\kappa_r)$ and $C(f(P+\kappa_n)+(1-f)l) \ll C(l)$, so both effects are strong, and donations are harmful.

6 Conclusion

Our analysis suggests several questions for future research that can be studied with modifications of the techniques we have developed. First, while we have considered resale, we have ignored recycling of used products. Recycling raises the novel issue of how consumers think about the recycled content of new goods, and more generally how they evaluate their impact in an economy with intermediate inputs. For instance, a consumer's purchase can affect the externality by changing the mix of inputs in the production of other units. Second, types of naivete beyond that we have analyzed appear plausible. As a simple example, a consumer may believe that the sale or donation of used goods always substitutes for new production and thus lowers the externality. Third, while we have taken the fragility f of products to be exogenous, it is fruitful to ask how this will be determined when the choice is endogenous. As an immediate point, socially responsible consumers dislike the harm they cause by replacing broken items, so they tend to prefer more durable products. But durability choices when consumers with different beliefs or social coefficients interact appears to be a non-trivial equilibrium phenomenon.

There are also relevant questions that call for more fundamental modifications of our theory. Perhaps most importantly, our framework ignores socially responsible consumers' potential motive to alter the beliefs of firms, investors, and innovators. In general, a consumer may buy expensive green products to signal that bringing these to the market is worth it. And in the context of secondary markets, a consumer may be reluctant to raise the price of used goods, lest she encourages future purchases of new goods. This can motivate responsible consumers to buy fewer or supply more used goods. To account for such motives, it is necessary to integrate uncertainty and inferences into our framework.

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A Proofs

For our welfare statements in Propositions 3 and 4 we will use the following obvious fact:

Fact 1. *Suppose that $l = 0$, and without the secondary market, everyone consumes more than socially optimal. If with the secondary market everyone's consumption is weakly higher and a positive share's consumption is strictly higher, then welfare is lower.*

Proof of Proposition 1. Notice that a consumer's objective function can be rewritten as

$$u(c_n + c_u) - e_n^k c_n - e_u^k c_u$$

where e_n^k and e_u^k are as stated in the proposition. Assume $e_n^k < e_u^k$. Since new and used goods are perfect substitutes but the effective price of new goods is strictly less, the consumer only buys new goods. Moreover, the consumer's optimal consumption of new goods has to solve $u'(c_n^*) - e_n^k = 0$. By Definition of $C(\cdot)$, therefore, $c_k = c_n^* = C(e_n^k)$. The case $e_n^k > e_u^k$ is analogous. If $e_n^k = e_u^k = e$, then the consumer's effective price of both types is identical and she is indifferent between them. Her optimal behavior only depends on the overall level which satisfies $u'((c_n + c_u)^*) - e = 0 \iff c_k = (c_n + c_u)^* = C(e)$. □

Proof of Proposition 2.

We first prove the claims regarding Q_c^* on page 15. Note first that since used products have positive marginal utility, we must have $p_u^* > 0$ and market clearing in a neighborhood of p_u^*.

If $r_n^* \neq r_u^*$, then there is a unique indifferent $k(p_u)$ such that $P + k(p_u) r_n^* = p_u + k(p_u) r_u^*$. Suppose that $r_n^* > r_u^*$; the other case is analogous. Then, consumers with $k < k(p_u)$ buy new, consuming a level $c_{k,n}$ that does not depend on p_u, and consumers with $k > k(p_u)$ buy used, consuming a level $c_{k,u}(p_u)$ that is differentiable in p_u with a negative derivative. Further, $c_{k(p_u),n} = c_{k(p_u),u}(p_u)$; and market clearing requires that $p_u^* > P$ and $k(p_u) \in (\underline{k}, \overline{k})$, so that $k(p_u)$ is linear with a positive slope. Hence, the demands for new and used products are $D_n(p_u) = \int_{\underline{k}}^{k(p_u)} c_{k,n} g(k) dk$ and $D_u(p_u) = \int_{k(p_u)}^{\overline{k}} c_{k,u}(p_u) g(k) dk$. This implies $D_n'(p_u) = k'(p_u) c_{k(p_u),n} g(k(p_u))$ and $D_u'(p_u) = -k'(p_u) c_{k(p_u),u}(p_u) g(k(p_u)) + \int_{k(p_u)}^{\overline{k}} c_k'(p_u) g(k) dk$. Hence, $Q_c^* = -D_n'(p_u^*)/D_u'(p_u^*) \in (0, 1)$.

If $r_n^* = r_u^*$, then $p_u = P$, since otherwise all consumers strictly prefer one of the two products, violating market clearing. Since raising current used consumption by a unit raises current production by Q_c^* and does not otherwise affect future production, we have $r_u^* = Q_c^* r_n^*$, i.e., $Q_c^* = 1$.

I $\Rightarrow$ II. Take an equilibrium described in I. Our derivation in the text establishes that either $Q_c^* = 1$, or Q_c^* satisfies Condition (5). But notice that $Q_c^* = 1$ satisfy the condition too. Further, by the continuity of utility in k, type k^* must be indifferent between the products. Again, we have shown that either $Q_c^* = 1$ and $p_u^* = P$, or an indifferent consumer satisfies the given condition; but notice that for $Q_c^* = 1$ and $p_u^* = P$, all types do. Finally, market clearing is obvious.

II $\Rightarrow$ I. Let r_n^* be defined by Equation (4) and $r_u^* = Q_c^* r_n^*$. Since Q_c^* satisfies Condition (5), the impacts r_n^* and r_u^* generate a cross-market effect equal to Q_c^*, and hence are consistent. Furthermore, Proposition 1 implies that if type k^* is indifferent, then types $k < k^*$ weakly prefer the new product, and types $k > k^*$ weakly prefer the used one. Hence, consumer behavior is consistent with equilibrium. Market clearing holds by construction.

We now prove the last statement. Again from our derivation, any steady-state competitive equilibrium implies a $Q_c^* \in [0, 1]$. Furthermore, if $Q_c^* < 1$, then there is a unique type k^* who is indifferent between new and used products, and types $k < k^*$ strictly prefer new, while types $k > k^*$ strictly prefer used. Hence, the equilibrium is described by I. If $Q_c^* = 1$, then $p_u^* = P$, and all consumers are indifferent between new and used products. In this case, each consumer's consumption level and utility are independent of which product she chooses, and so is production and social welfare. Hence, any such equilibrium is payoff-equivalent to one in which we choose k^* such that types $k < k^*$ buy new and types $k > k^*$ buy used, and market clearing holds. $\square$

Proof of Proposition 3. I. Assuming $Q_c^* = 1$ the first equilibrium condition

$$Q_c^* = \frac{(1-(1-f)(1-Q_c^*))g(k^*)c_{k^*}}{(1-(1-f)(1-Q_c^*))g(k^*)c_{k^*} - f(1-Q_c^*)\int_{k^*}^{\overline{k}}(1/u''(c_k))g(k)dk}$$
$$= \frac{(1-0)g(k^*)c_{k^*}}{(1-0)g(k^*)c_{k^*} + 0} = 1$$

is fulfilled. The second condition

$$f(1-Q_c^*)k^* = (p_u^* - P)(1-(1-f)(1-Q_c^*)) \iff f0k^* = (p_u^* - P)1 \iff p_u^* = P$$

is independent of k^*, i.e., in equilibrium every consumer is indifferent between new and used goods. Setting $p_u^* = P$, the consumption levels given by Proposition 1 are independent of the type of good consumers consume. Let c_k denote the (equilibrium) consumption levels as determined by Proposition 1. Now define

$$\Phi(l) = (1-f)\int_{\underline{k}}^{l} c_k g(k)dk - f\int_{l}^{\bar{k}} c_k g(k)dk$$

and notice that it is continuous with $\Phi(\underline{k}) < 0$ and $\Phi(\bar{k}) > 0$. Hence, there is l^* such that $\Phi(l^*) = 0$. Now setting $k^* = l^*$ ensures that the market clearing condition is satisfied. Since the levels c_k where determined by Proposition 1, all consumers are indifferent between used and new goods, and hence so is k^*. This proves the existence of the proposed equilibrium. Moreover, by the monotonicity of Φ and the requirement that $p_u^* = P$ has to hold, up to this is the essentially unique equilibrium with $Q_c^* = 1$ (up to the allocation which consumer consumes which type of good).

The effective prices a consumer faces are $e_n^k = e_u^k = f(P+k)$, and hence each consumer's consumption level is exactly as without a secondary market. Since the difference in allocation of new and used goods has no welfare effect, welfare is as it is without a secondary market.

II. In any other equilibrium $Q_c^* < 1$. Fix such an equilibrium. We prove that for any k, the effective price faced by the consumer is strictly lower than $f(P+k)$ which is the effective price in the equilibrium above.

Take first consumers who buy new. For these consumers, Part 1 of Proposition 1 implies

$$p_u^* - P > \frac{f(1-Q_c^*)}{1-(1-f)(1-Q_c^*)}k. \tag{8}$$

Hence, the effective price satisfies

$$\begin{aligned} P-(1-f)p_u^* + k\frac{f}{1-(1-f)(1-Q_c^*)} &= fP - (1-f)(p_u^*-P) + k\frac{f}{1-(1-f)(1-Q_c^*)} \\ &< fP - \frac{(1-f)kf(1-Q_c^*)}{1-(1-f)(1-Q_c^*)} + k\frac{f}{1-(1-f)(1-Q_c^*)} \\ &= fP + kf\frac{1-(1-f)(1-Q_c^*)}{1-(1-f)(1-Q_c^*)} = f(P+k). \end{aligned}$$

Now consider consumers who buy used. The same derivation as for consumers who buy new shows that that for k^*, the effective price stays the same as without a secondary market. Furthermore, among consumers who strictly buy used, we have that

$$\frac{\partial e_u^k}{\partial k} = \frac{Q_c^* k f}{Q_c^* + f(1-Q_c^*)} < kf = \frac{\partial f(P+k)}{\partial k}$$

the effective price rises slower if $Q_c^* < 1$ than without a secondary market (or when $Q_c^* = 1$). Therefore, almost all consumers consume strictly more. Notice that consumers' consumption without a secondary market is $C(f(P+k))$ which is too high from a social perspective, since $k < K$ for all k. Since every consumer's consumption weakly increases and does so strictly for a positive share, Fact 1 yields that welfare must be lower.

III. Let $\underline{g} = \inf\{g(x)|x \in supp(g)\}$.

In order to have an equilibrium with $Q_c^* < 1$, the following condition needs to hold:

$$Q_c^* = \frac{(1-(1-f)(1-Q_c^*))g(k^*)c_{k^*}}{(1-(1-f)(1-Q_c^*))g(k^*)c_{k^*} + f(1-Q_c^*)\int_{k^*}^{\overline{k}}(-1/u''(c_k))g(k)dk} = \frac{A}{A+f(1-Q_c^*)B}$$

Note that we moved the minus sign under the integral for convenience, so that both A and B are strictly positive. We will show that there is a $\underline{g}$ sufficiently large s.t. for every $Q_c^* < 1$, the RHS strictly exceeds the LHS. That is, we will show that $Q_c^* < \frac{A}{A+f(1-Q_c^*)B}$. Thus, assume that $Q_c^* < 1$, then we have:

$$Q_c^* < \frac{A}{A+f(1-Q_c^*)B} \iff Q_c^* A + Q_c^* f(1-Q_c^*)B < A$$
$$\iff Q_c^* f(1-Q_c^*)B < (1-Q_c^*)A \iff Q_c^* fB < A$$

where the last equivalence follows because we assume that $Q_c^* < 1$. Moreover, it is sufficient to show that $fB < A$. Spelling out A and B, we get that this is equivalent to

$$g(k^*) > \frac{f}{1-(1-f)(1-Q_c^*)c_{k^*}} \int_{k^*}^{\overline{k}} (-1/u''(c_k))g(k)dk \tag{9}$$

Note that, independent of $\underline{g}$, c_{k^*} is bounded below by $c_{\overline{k}}$ and that $1-(1-f)(1-Q_c^*)$ is bounded below by f, hence the initial fraction is strictly bounded. Thus we only need to bound the integral. However, let $m = \max_{\underline{k},\overline{k}}(-1/u''(c_k))$, which exists and is finite, since the function is continuous and c_k is bounded away from 0 for all k we consider, thus the term doesn't blow up. Hence the integral is strictly less than $\int_{\underline{k}}^{\overline{k}} mg(k)dk = m$. Therefore the term on the right in equation (9) is bounded above, so if $\underline{g}$ is larger than this bound, we have no other equilibrium. This proves the claim.

Claim: For every $q \in [0,1]$, there is a unique $k(q)$ and $p_u(q)$ that satisfy

$$f(1-q)k(q) = (p_u(q) - P)(1-(1-f)(1-q)) \tag{10}$$

$$S(q,k(q)) \equiv (1-f)\int_{\underline{k}}^{k(q)} c_{k,n} g(k)dk = f\int_{k(q)}^{\overline{k}} c_{k,u} g(k)dk \equiv D(q,k(q)) \tag{11}$$

Proof of claim: Let $p_u(q,k)$ be the unique solution to $f(1-q)k = (p_u(q,k) - P)(1-(1-f)(1-q))$. Then we have that $S(q,\underline{k}) = 0$ and $D(q,\underline{k}) = f\int_{\underline{k}}^{\overline{k}} c_{k,u} g(k)dk > 0$, as $c_{k,u} > 0$ for all k. Similarly, $S(q,\overline{k}) = (1-f)\int_{\underline{k}}^{\overline{k}} c_{k,n} g(k)dk > 0 = D(q,\overline{k})$. Moreover, $S(q,k)$ is strictly increasing in k, while $D(q,k)$ is strictly decreasing in k: first, the range over which we integrate is increasing for S and decreasing for D. Further, $p_u(q,k)$ is strictly increasing in k. Hence for $k' < k$, we have that $c_{k',n}$ is increasing in $p_u(q,k)$, hence the integral - i.e., S – is strictly increasing in k. When $k' > k$, then $c_{k',u}$ is decreasing in $p_u(q,k)$, since consumers have to pay the price of the used good. Thus $D(q,k)$ is strictly decreasing in k. Hence there is a unique k s.t. $S(q,k) = D(q,k)$ holds for $p_u(q,k)$. This is $k(q)$, and $p_u(q) = p_u(q,k(q))$. This proves the claim.

Now take some $q \in (0,1)$, we will use $q = 0.5$. Then let $k_0 = k(0)$, and consider some $\varepsilon > 0$. We will construct $\hat{G}$ s.t. $\hat{k}(q) = k(q)$, and hence $\hat{p}_u(q) = p_u(q)$, with $\hat{g}(k(q)) = \varepsilon$. To construct this $\hat{G}$, define

$$H_a(x,\varepsilon) = \begin{cases} 0 \text{ if } x \le a - \varepsilon \\ 1 \text{ if } x \ge a + \varepsilon \\ \frac{1}{2\varepsilon}(x - a + \varepsilon) \text{ for } x \in (a-\varepsilon, a+\varepsilon) \end{cases}$$

Next we define $\hat{g}$ as follows, for some $\varepsilon_2 > 0$:

$$\hat{g}(x) = g(x) + (g(x) - \varepsilon)\left(H_{k(q)+\lambda\varepsilon}(x,\varepsilon_2) - H_{k(q)-\varepsilon}(x,\varepsilon_2)\right)$$

We will deal later with the fact that this $\hat{g}$ does not integrate to 1 and thus is not a probability density.

Except for buffer intervals of size ε_2 on either side, this function equals $g(x)$ outside of $[k(q) - \varepsilon, k(q) + \lambda\varepsilon]$, and equals ε within (again except on buffer-zones that dependent on ε_2). In what follows we denote with $R(\varepsilon_2)$ all terms coming from these buffers (this is a slight abuse of notation, since the terms vary). It is straightforward that as $\varepsilon_2 \to 0$ we have $R(\varepsilon_2) \to 0$. We pick λ s.t. market clearing holds under q, $k(q)$, and $p_u(q)$ with the new distribution. This is possible, since the new supply is

$$\hat{S}(q,k(q)) = (1-f)\int_{\underline{k}}^{k(q)} c_{k,n}\hat{g}(k)dg = (1-f)\left(\int_{\underline{k}}^{k(q)-\varepsilon} c_{k,n}g(k)dk + \int_{k(q)-\varepsilon}^{k(q)} \varepsilon c_{k,n}dk + R(\varepsilon_2)\right),$$

so that $S(q,k(q)) - \hat{S}(q,k(g)) = (1-f)\int_{k(q)-\varepsilon}^{k(q)} c_{k,n}(g(k)-\varepsilon)dg + R(\varepsilon_2)$. As for the new demand, we have

$$\hat{D}(q,k(q)) = f\int_{k(q)}^{\overline{k}} c_{k,u}\hat{g}(k)dg = f\left(\int_{k(q)}^{k(q)+\lambda\varepsilon} c_{k,u}\varepsilon dg + \int_{k(q)+\lambda\varepsilon}^{\overline{k}} c_{k,u}g(k)dg + R(\varepsilon_2)\right)$$

so that $D(q,k(q)) - \hat{D}(q,k(q)) = f\int_{k(q)}^{k(q)+\lambda\varepsilon} c_{k,u}(g(k)-\varepsilon)dg + R(\varepsilon_2)$. Note that $D(q,k(q)) = S(q,k(q))$ by construction of $k(q)$ to satisfy market clearing, so

$$\hat{D}(q,k(q)) - \hat{S}(q,k(q)) = (1-f)\int_{k(q)-\varepsilon}^{k(q)} c_{k,n}(g(k)-\varepsilon)dg - f\int_{k(q)}^{k(q)+\lambda\varepsilon} c_{k,u}(g(k)-\varepsilon)dg + R(\varepsilon_2).$$

For $\lambda = 0$, this difference is strictly positive for sufficiently small ε_2 (depending on ε). For sufficiently large λ, this difference is equal to $(1-f)\int_{k(q)-\varepsilon}^{k(q)} c_{k,n}(g(k)-\varepsilon)dg - f\int_{k(q)}^{\overline{k}} c_{k,u}(g(k)-\varepsilon)dg + R(\varepsilon_2)$, with the terms depending on ε being strictly negative for sufficiently small ε.

Thus for all ε such that this holds, we can find ε_2 small enough and λ large enough so that the difference in demand and supply is given by the above, which is strictly negative. Hence for small enough ε_2, the difference is strictly positive at $\lambda = 0$ and strictly negative at some large λ, and continuous in between, hence there is some $\lambda(\varepsilon)$ such that the difference is 0.

Moreover, $\lambda(\varepsilon)\varepsilon \to 0$ as $\varepsilon \to 0$. If this was not the case, then $\hat{D}(q,k(q))$ would be strictly lower than $D(q,k(q))$ as ε and ε_2 converge to 0, yet $\hat{S}(q,k(q))$ converges to $S(q,k(q))$, so that $\lim \hat{D}(q,k(q)) - \hat{S}(q,k(q)) < 0$ as $\varepsilon \to 0$, even though $\hat{D}(q,k(q)) = \hat{S}(q,k(q))$ for all $\varepsilon > 0$. This is a contradiction.

Thus we have a new density function $\hat{g}$ s.t. both conditions (10) and (11) hold for the old values of $k(q)$ and $p_u(q)$, since condition (10) does not depend on the distribution, and since $\lambda(\varepsilon)$ is s.t. condition (11) holds. Moreover $\hat{g}(k(q)) = \varepsilon$.

As mentioned above, this $\hat{g}$ does not integrate to 1, but we can scale $\hat{g}$ by the same factor everywhere, to obtain $a^{-1}\cdot\hat{g}(k)$, where $a = \int_{\underline{k}}^{\overline{k}} \hat{g}(k)dg$, with $a \to 1$ as as $\varepsilon \to 0$. Let $\hat{h}(k) = a^{-1}\hat{g}(k)$. Then $\hat{h}$ satisfies conditions (10) and (11) with the old values of $k(q)$ and $p_u(q)$, the first since it doesn't depend on the distribution, the second since market clearing isn't affected by a multiplicative rescaling of the distribution, and we have that

$\hat{h}(k(q)) = a^{-1}\varepsilon$.

Now we are ready to consider the final equilibrium condition which determines Q_c^*, but to do so for $\hat{h}$ instead of g:

$$Q_c^*(q) \equiv \frac{(1-(1-f)(1-q))\hat{h}(k(q))c_{k(q)}}{(1-(1-f)(1-q))\hat{h}(k(q))c_{k(q)} - f(1-q)\int_{k(q)}^{\overline{k}}(1/u''(c_k))\hat{h}(k)dk}$$

Note that if we find a q s.t. $Q_c^*(q) = q$, then for this q we have that all the equilibrium conditions hold, and hence we have identified an equilibrium.

It is clear that $Q_c^*(0) > 0$ by plugging in $q = 0$. Moreover, picking $q = 0.5$, we know that $\hat{g}(k(q)) = \varepsilon$, hence we have

$$Q_c^*(0.5) = \frac{(1-0.5(1-f))\varepsilon c_{k(0.5)}}{(1-0.5(1-f))a^{-1}\varepsilon c_{k(0.5)} - 0.5f\int_{k(0.5)}^{\overline{k}}(1/u''(c_k))\hat{h}(k)dk}$$

The second term in the denominator, $-0.5f\int_{k(0.5)}^{\overline{k}}(1/u''(c_k))\hat{h}(k)dk$ is strictly positive and strictly bounded away from 0, since market clearing requires that $k(0.5)$ cannot equal $\overline{k}$. Hence $Q_c^*(0.5) \to 0$ as $\varepsilon \to 0$, hence there is $\varepsilon > 0$ s.t. $Q_c^*(0.5) < 0.5$.

But then, since $Q_c^*(q)$ is continuous in q, there must be some $q \in (0, 0.5)$ s.t. $Q_c^*(q) = q$, and thus we have an equilibrium with $Q_c^* < 1$. Finally note that $\hat{h}$ and g only differ by an arbitrary small amount except on an arbitrarily small range (where they differ a discrete amount). Hence, a suitable $\hat{H}$ can be chosen arbitrarily close to G.

□

Proof of Proposition 4. If $k < p_u^* - P$, then a naive consumer buys new products, and sells the remainder the following period. Furthermore, she consumes $C\left(P - (1-f)p_u^* + k\right)$ units. If $k > p_u^* - P$, then she prefers to buy used products and consumes $C\left(fp_u^*\right)$ units. Notice that the only variable influencing consumers optimal consumption is p_u^*. The total amount of demanded used goods is $(1 - G(p_u^* - P))C(fp_u^*)$. This is continuous and strictly decreasing in p_u^*. Moreover, it is larger than 0 if $p_u^* = P$ and 0 if $p_u^* = P + \bar{k}$. The total amount of supplied used goods is $\int_{\underline{k}}^{(p_u^*-P)} C\left(P - (1-f)p_u^* + k\right) g(k)dk$, which is continuous and strictly increasing in p_u^*. Moreover, it is 0 if $p_u^* = P$ and larger 0 if $p_u^* = P + \bar{k}$. Hence, there exists a unique p_u^* at which the market for used goods clears and consumers behave optimally. Moreover, $p_u^* > P$ has to hold in this equilibrium. Without a secondary market the consumption of type k is determined by the effective price $f(P+k)$. Assuming $k < p_u^* - P$

the consumer buys new and her effective price is $P-(1-f)p_u^*+k < P-(1-f)(k+P)+k = f(P+k)$. If $k > p_u^* - P$, she buys used and faces the effective price $fp_u^* < f(P+k)$. In both cases the consumers consumes strictly more. If $k = p_u^* - P$, then she faces an effective price of $fp_u^* = f(P+k)$ and consumes exactly as much as without a secondary market. By Fact 1 welfare is strictly lower than without a secondary market. □

Proof of Proposition 5.

A. First, we will identify which good the selfish and the responsible consumers buy. From equation (1), it is clear that switching from one unit of new to used good leads to a change in utility of $-l + P - p_u^* + k \cdot (r_n^* - r_u^*)$: the consumption utility decreases by l, the price paid today decreases by $P - p_u^*$, and the externality generated decreases by $r_n^* - r_u^*$, while the resale price tomorrow is the same.

Since in every equilibrium we have $p_u^* \geq 0$, and since we assume that $P < l$, we have that $P - p_u^* - l < 0$ which is the net benefit of a selfish person with $k = 0$ from switching to used goods. Since this is negative, selfish consumers always buy new goods.

Consider an equilibrium with price $p_u^* \geq 0$. Responsible consumers' net utility from switching to used goods is strictly increasing in $\Delta(r) \equiv r_n^* - r_u^*$, so there is some $\bar{r}$ such that they strictly prefer buying new goods when $\Delta(r) < \bar{r}$, used goods when $\Delta(r) > \bar{r}$, and are indifferent when $\Delta(r) = \bar{r}$ which implies $\kappa\bar{r} = p_u^* - P + l$. Note that we assumed that $P + \kappa > l$, thus $P + \kappa > l = P - p_u^* + \kappa\bar{r}$, hence $1 > \bar{r}$.

Case 1: $\Delta(r) < \bar{r}$. Then both selfish and responsible consumers strictly prefer new goods, and no one buys or uses used goods. Then $r_n^* = 1$, as each new good bought causes 1 unit of pollution this period, and does not alter future pollution since it is thrown away after one period. Moreover, since no one buys used goods at price p_u^*, we have an oversupply and market clearing doesn't hold, so we must have $p_u^* = 0$ (the only price at which we can have oversupply). Thus buying a unit of used goods does not affect anyone else's choices, it merely reduces the oversupply of used goods, and thus $r_u^* = 0$. Since $1 > \bar{r} - p_u^* = \bar{r}$, we also have $\Delta(r) < 1$. But $r_n^* = 1$ and $r_u^* = 0$ implies that $\Delta(r) = 1$, hence we have a contradiction. So $\Delta(r) < \bar{r}$ cannot hold in any equilibrium.

Case 2: $\Delta(r) = \bar{r}$**.** Then responsible consumers are indifferent between the two goods. There are two subcases.

First, if market clearing holds, then demand equals supply of used goods and $p_u^* \geq 0$. Then if a person switches from new to used forces another consumer who currently bought a used good - a socially responsible consumer who is indifferent between used and new - to switch to the new good. Hence buying new and used goods is equivalent, i.e., $\Delta(r) = 0$. But if $\Delta(r) = 0$, the net benefit from switching is $-l + P - p_u^* \leq -l + P < 0$, hence socially responsible consumers strictly prefer buying new. Hence market clearing cannot hold, hence there cannot be an equilibrium.

Second, if market clearing doesn't hold, then there is an oversupply and $p_u^* = 0$. In this case, when a person switches from used to new, this causes a strict oversupply of used goods. Since responsible consumers are indifferent, this means that there are many possible responses to this behavior: other responsible consumers as a group may switch anywhere from 0 to 1 unit of their consumption from new to used, which is consistent with many r_u^*, so we do not have a unique well-defined equilibrium as required by our definition.

Case 3: $\Delta(r) > \bar{r}$**.** Then responsible consumers strictly prefer the used good. Then if a person switches from used to new, even though this may have a small price impact, because both types of consumers have strict preferences (no one is indifferent), their choices remain the same today. Thus today's production goes up by 1 unit. While this leads to $(1-f)$ extra units of used goods tomorrow (and $(1-f)^2$ extra units in two days and so on), none of this affects future production of new goods: the selfish will buy as before, the socially responsible consumers are still not buying any new goods, hence the total impact is 1 unit. Hence $\Delta(r) = 1 > \bar{r}$, with $r_n^* = 1$ and $r_u^* = 0$.

Summary. We have thus established that in every equilibrium we must have $\Delta(r) = 1 > \bar{r}$, and that (i) selfish consumers strictly prefer and buy new goods, and since they face the effective price of $P - (1-f)p_u^*$, they consume an amount $C(P - (1-f)p_u^*)$; and (ii) socially responsible consumers strictly prefer and buy used goods, and since they face the effective price of $l + fp_u^*$, they consume an amount $C(l + fp_u^*)$.[16] Note that $\Delta(r) = 1$ implies that $Q_c^* = 0$.

In order to establish that we can have such an equilibrium, we need to find a p_u^* s.t. market clearing holds given the above demand from consumers. Let $\bar{g}$ be such that $\frac{\bar{g}}{1-\bar{g}} = \frac{f}{1-f}\frac{C(P)}{C(l)}$ and $\underline{g}$ be such that $\frac{\underline{g}}{1-\underline{g}} = \frac{f}{1-f}\frac{C(l+fp_u^+)}{C(P-(1-f)p_u^+)}$, where $p_u^+ = P + \kappa - l$.

To make welfare comparisons, we first solve for the case when there is no secondary market. Selfish consumers consume $C(P)$, buying new goods and throwing them away after one period of use. Note that now c_u is taken as given, as used goods can neither be sold nor bought, only consumed or thrown away. A marginal increase in new consumption today costs $P + \kappa$ for a socially responsible consumer and brings an additional increase in marginal utility of $u'(C)$ today (where $C = c_u + c_n$), $(1 - f)(u'(C) - l)$ tomorrow due to having an extra amount of $1 - f$ of used goods, $(1 - f)^2(u'(C) - l)$, and so on. Solving this leads to $u'(C) = f(P + \kappa) + l(1 - f)$, thus responsible consumers face an effective price of $f(P + \kappa) + l(1 - f)$ and consume $C(f(P + \kappa) + l(1 - f))$ of goods every period, buying a fraction f of this new to replace broken goods.

I. If $g \in (\bar{g}, 1)$, then at $p_u = 0$ socially responsible consumers demand $(1 - g)fC(l)$ and selfish provide $g(1 - f)C(P)$. Since $(1 - g)fC(l) < (1 - \bar{g})fC(l) = \bar{g}(1 - f)C(P) < g(1-f)C(P)$, there is oversupply, so that $p_u^* = 0$ is an equilibrium. It is also clear that every $p_u^* > 0$ leads to oversupply, and thus can't be part of an equilibrium. Notice that the selfish are consuming the same amount as without secondary markets, so that their contribution to new production and hence to externalities is the same. As for socially responsible consumers, they used to consume per period in total, a fraction f of which in new goods, a fraction $(1-f)$ in used. Now they consume $C(l)$.

Since the consumption of used goods is socially more efficient than producing new ones, and in this equilibrium, consumption levels are weakly higher while production is lower, welfare is strictly higher.

[16]The effective price for selfish consumers consists of having to pay P per unit bought, and receiving p_u^* for each of the $1 - f$ unbroken used units tomorrow. The effective price for the socially responsible consumers consists of the marginal cost l from using used goods, plus paying the price p_u^* for buying used goods to replace the fraction f of broken used goods. There is no cost from externlities for the selfish who don't care, or for the socially responsible who consume used goods that cause no externalities in the remaining type of equilibrium.

II. When $g \in (\underline{g}, \overline{g})$, then $(1-g)fC(l) > (1-\overline{g})fC(l) = \overline{g}(1-f)C(P) > g(1-f)C(P)$, so that used demand is too high for an equilibrium with $p_u^* = 0$. Hence, $p_u^* > 0$ has to hold for markets to clear. To show that such a market-clearing p_u^* exists, let $D(p_u^*) \equiv (1-g)fC(l+p_u^*)$ be the demand and $S(p_u^*) \equiv g(1-f)C(P-(1-f)p_u^*)$ the supply at price p_u^*. Then $D(0) > S(0)$ while $D(p_u^+) = (1-g)fC(l+fp_u^+) < (1-\underline{g})fC(l+fp_u^+) = \underline{g}(1-f)C(P-(1-f)p_u^+) < g(1-f)C(P-(1-f)p_u^+) = S(p_u^+)$. Hence, since $C(\cdot)$ is continuous and strictly monotone in p_u^*, there is a unique $p \in (0, p_u^+)$ s.t. $D(p_u^*) = S(p_u^*)$ and thus market clearing, holds.

Since $p_u^* > 0$, the effective price $P-(1-f)p_u^*$ of selfish consumers is strictly lower than P. Moreover, $p_u^* < p_u^+$ implies that $l + fp_u^* < l + f(P+\kappa-l) = f(P+\kappa) + l(1-f)$. Hence, the effective price for both types of consumers is strictly lower than without a secondary market and consumption is higher.

III. Notice from the above that for $p_u \leq p_u^+$ the market does not clear when $g < \underline{g}$. Hence, there cannot be any equilibrium with $p_u \leq p_u^+$. When $p_u > p_u^+$ the effective price of the used good for socially responsible consumers is $l + fp_u > l + fp_u^+ = l + f(P+\kappa-l) = f(P+\kappa)+(1-f)l$, while the effective price for new goods is $P+\kappa-(1-f)p_u^* = P+\kappa-(1-f)(P+\kappa-l) = f(P+\kappa)+(1-f)l$. Thus the socially responsible consumers would strictly prefer the new goods, which contradicts what we derived previously (see Summary above), and hence there cannot be an equilibrium. Therefore we cannot have any equilibrium in this case.

B. Take any $p_u^* \in (0, P+\kappa-l)$. We show that a $u(\cdot)$ exists such that the resulting equilibrium satisfies the statement and has used price p_u^*. We use the following obvious fact:

Fact 2. *Suppose* $0 < c_1 < c_2 < c_3 < c_4$ *and* $e_1 > e_2 > e_3 > e_4 > 0$. *Then, there is a* $u(\cdot)$ *satisfying our assumptions such that* $C(e_m) = c_m$ *for each* $m = 1, 2, 3, 4$.

Consider any $M > 0$. By the above fact, for sufficiently small $\epsilon > 0$ we can choose a $u(\cdot)$ such that $C(f(P+\kappa-l)+l) = M$, $C(fp_u^*+l) = M+\epsilon$, $C(P) = M+2\epsilon$, and $C(P-(1-f)p_u^*) = M'$, where $M' \equiv (1-g)f(M+\epsilon)/(g(1-f)) > (M+\epsilon)/f > M/f$.

By construction, we are in Case II of Part A, so there is a unique equilibrium. Again by construction, there is an equilibrium of the type in Case II — and thus the unique one — in which the used price is p_u^*, responsible types consume $M+\epsilon$, and selfish types consume M'.

Production per period is gM' with the secondary market, and

$$g(M+2\epsilon)+(1-g)fM < g(M+2\epsilon)+(1-g)f(M+\epsilon) = g(M+2\epsilon)+g(1-f)M'$$

without the secondary market. Since $fM' > M$, for a sufficiently small ϵ production is higher with the secondary market.

Total net private consumption utility with the secondary market is

$$g(u(M') - PM') + (1-g)(u(M+\epsilon) - l(M+\epsilon)),$$

and without the secondary market it is

$$g(u(M+2\epsilon) - P(M+2\epsilon)) + (1-g)(u(M) - (1-f)lM - fPM)$$

For a sufficiently small ϵ, both components are larger than above: the first one because $u(M') - u(M+2\epsilon) < u'(M+2\epsilon)(M' - (M+2\epsilon)) = P(M' - (M+2\epsilon))$, and the second one because $l > P$ and $u'(M)$ is finite. □

B A Small Consumer's Impact on Production

In this section, we restate the main insight in Section II.A of Kaufmann et al. (2024) in a different way. This motivates our definition of a consumer's impact in Section 2.

For simplicity, we use Kaufmann et al.'s static framework; adapting the analysis to our dynamic setting is notationally heavy, but does not change the logic. To understand a small consumer's impact, we use a "replicator economy:" we introduce identical copies of the other participants, and let the number of copies approach infinity. Suppose, then, that our single individual enters a market with I other consumers and I suppliers. The other consumers all have the same demand curve $D(p)$, and the suppliers all have the same supply curve $S(p)$. Both curves are continuously differentiable, with $D'(p) < 0$ and $S'(p) > 0$ everywhere. There is a price $p^* > 0$ for which $S(p^*) = D(p^*)$.

The market mechanism is the following. First, the individual submits her demand $c \in \mathbb{R}$. Then, the price $p_I(c) > 0$ is chosen to clear the market, i.e., to satisfy $c + ID(p_I(c)) = IS(p_I(c))$; suppose that $p_I(c)$ exists and is unique for all I and c of interest. Finally, the equilibrium quantity $q(c) = IS(p_I(c))$ is produced and consumed.

A vanishingly small consumer's impact on the price is then obviously zero: for any c,

$\lim_{I\to\infty} p(c) = p^*$. For her impact on production, note that $c + ID(p_I(c)) = IS(p_I(c))$ is equivalent to $c/I + D(p_I(c)) = S(p_I(c))$, so that $p_I(c) = p_1(c/I)$. Hence, the individual's impact is

$$IS(p_I(c)) - IS(p_I(0)) = \frac{S(p_1(c/I)) - S(p_1(0))}{1/I} = c \cdot \frac{S(p_1(c/I)) - S(p_1(0))}{c/I}$$

Taking the limit yields that a vanishingly small consumer's impact is

$$c \cdot \lim_{I\to\infty} \frac{S(p_1(c/I)) - S(p_1(0))}{c/I} = c \cdot r^*,$$

where r^* is the marginal effect of shifting demand in an economy with representative demand curve $D(\cdot)$ and supply curve $S(\cdot)$ (i.e., the derivative of production with respect to Δ at $\Delta = 0$ when the demand curve is $\Delta + D(p)$ and the supply curve is $S(p)$). Our definition of r_n^* and r_u^* adapts this observation to our more complicated setting.