Prices, Politics and Persuasion: The Case of Pollution Control and Clean Technology Adoption

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Abstract
This paper presents three simple models to study how prices, politics and persuasion may each play a role in environmental policymaking. Our conclusions are twofold. First, in the absence of increasing returns, requiring the polluting industry to purchase pollution permits can internalize the negative externality of pollution, and the optimal price of pollution permits should increase with the disutility of pollution. Second, with increasing returns in the industry using clean technologies, it is welfare enhancing to complement the pollution permits policy with a tax-funded subsidy to the clean industry, or with a tax-funded public campaign to persuade consumers to move away from the pollution generating goods.

JEL classification: D83, H23
Keywords: pollution permits, increasing returns; advertising

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1. Introduction

Kenneth Boulding (1981) succinctly summarizes the main coordination processes of human activities with three “p” words: prices, politics, and preachment. “Prices” refer to the market mechanism. Prices that emerge from voluntary market transactions convey the most essential information which guides the decisions of relevant market participants (Hayek, 1945). “Politics” includes both the legal system and other government institutions that rely on legal or political power to maintain some intended order. “Preachment”, or alternatively a somewhat less paternalistic “p” word, “persuasion”, refers to the use of information, ideas, reasoning, pleading and the like to influence people’s perceptions, preferences and therefore actions.

The three “p”s of the coordination processes interact with one another. For example, since market exchanges are essentially exchanges of property rights between property owners, the market mechanism needs to work on the basis of a system of private property rights. Social conventions as well as legal and political institutions play a vital role in the definition and maintenance of private property rights. Where private property rights are clearly defined and maintained, the “invisible hand” of the market coordinates the actions of self-interested individuals which result in public gain (Smith, 1776). Where private property rights are too costly to define or to maintain, the problem of externalities arises and a greater reliance on coordination through politics and persuasion is called for because unfettered market coordination may not lead to the best achievable outcome. The greater reliance of politics and persuasion may take different forms. For instance, Pigou (1932) proposes the use of taxes/subsidies to internalize
negative/positive externalities. Coase (1960) sees externality as a problem of a reciprocal nature and advocates property right assignments that avoid the more serious harm. Ostrom (1990) provides examples of successful collective solutions to externality problems and highlights the importance of governance designs that foster mutual trust and commitment to agreed rules for the common good. Nyborg, Howarth, and Brekke (2006) suggest that an equilibrium that has a high demand for environmentally friendly “green” products can be achieved through advertising that influences people’s beliefs.

The purpose of this paper is to present three models of pollution control and clean technology adoption to illustrate how prices, politics and persuasion may interact to potentially improve welfare in circumstances where the unfettered market does not lead to the best achievable outcome.

Standard economic theory suggests that markets fail (compared to the competitive equilibrium ideal) in the presence of externalities. In the case of pollution control, there are likely to be two distinct and important externalities: a negative externality of pollution; and positive externalities related to the discovery and adoption of clean technologies (Jaffe, Newell, & Stavins, 2005). Accordingly, two different types of policy instruments may be desirable to address these two market failures. In practice, many different policies may be adopted and there may be an optimal portfolio of policies for a specified environmental objective. In this paper, we consider two different policy combinations. The first is pollution permits (the polluting industry is required to purchase) combined with tax funded subsidies to the clean technology industry. The second is pollution permits combined with tax-funded advertising to promote clean technology adoption. The first combination has a “price” for the right to pollute, a tax and a subsidy which are tools of “politics”. The second combination introduces an additional
coordination tool: persuasion through advertising. We show that both policy combinations are superior to using pollution permits alone.

Our result supports Heinzel and Winkler (2011) and Sartzetakis & Tsigaris (2005) who show that technology policy should complement environmental policy to achieve the socially optimal path. It is also consistent with Fischer and Newell (2008) who find that an optimal portfolio of environmental policies include both an emissions price and subsidies for technologies, R&D and learning.

Compared to the aforementioned studies, our paper has two distinct features. First, it highlights the externalities resulting from the existence of fixed cost in production which gives rise to increasing returns and affects the varieties of products that is desirable to supply (Spence, 1976). There is a growing recognition in the literature that increasing returns in production are theoretically important (Arrow, Ng and Yang, 1998; Buchanan and Yoon, 1994), empirically significant (Antweiler & Trefler, 2002; Fingleton, 2003), and relevant for public policy (Ng & Zhang, 2007). Increasing returns are studied in the context of economies of specialisation (see Cheng and Yang 2004 for a survey) or more commonly in monopolistic competition models pioneered by Dixit and Stiglitz (1977). This paper extends Dixit and Stiglitz’s (1977) monopolistic competition model to include negative externality from pollution to study the environmental policy in the presence of increasing returns. In our view, the monopolistic competition model captures two key characteristics of the clean technology industry well: first, the importance of fixed costs, for example, the cost of research and development; and second, competition among different product varieties.

Another distinct feature of our paper is that it points to advertising as legitimate environmental policy tool. There is some debate in the literature on how persuasion through
advertising may change individual behaviour. Some economists believe that individual preferences are stable and therefore cannot be changed by advertising. For example, Becker (1976) sees stable preference as one of the key assumptions that “form the heart of the economic approach” (p.5). On the other hand, Dixit & Norman (1978) suggest that advertising can change consumer tastes. In more recent literature, it is argued that even if advertising does not change people’s tastes, it can change people’s perceptions, and therefore alter their behaviour. For example, Nyborg, Howarth, and Brekke (2006) suggest that advertising may permanently increase green consumption by influencing individual beliefs about the external effects of their consumption or about others’ people behavior. Specifically, an individual is more likely to increase their green consumption if he/she perceived a larger environment costs associated with non-green consumption, or if he/she perceives that other people consume more green goods.

The observation that advertising does lead to more environmentally friendlier behavior many be explained by the availability heuristic, which is the phenomenon that people infer the prevalence of an event based on the ease with which the event can be recalled or imagined (Tversky and Kahneman, 1973). Advertising makes the event advertised, for example, environmental damage due to pollution, more easily recalled or imaged, and therefore affect people’s perceptions about the consequences of pollution. For example, in 2005, the state government of Victoria in Australia launched a campaign to urge Victorian households to cut greenhouse gas emissions. The TV advertisement in the campaign featured black balloons, each representing 50 grams of greenhouse gas. The average Victorian household produces about 213,000 black balloons a year which is much easier to visualise than 10.7 tonnes of carbon pollution! The idea of using black balloons to measure greenhouse gas emission proved to be very powerful, and was adopted by other state governments in Australia.

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In this paper, we take the view that advertising changes individuals’ perceptions about their individual contribution to the environmental damage of pollution, and that individuals act on the basis of their perceptions.

In the following section, we present a set of three models to study the role of prices, politics and persuasion in environmental policymaking. The first model is a base model with only one externality: the negative externality of pollution. From this model we obtain the optimal price for pollution permits in the absence of increasing returns. The second model and the third model introduce increasing returns in the industry that uses clean technology. The second model examines the policy combination of pollution permits and subsidy to the clean technology industry; and the third model considers the policy combination of pollution permits and tax-funded advertising to discourage consumption of the polluting industry’s products. We summarise our findings and discuss the limitations of the models in section 3.

2. Models

2.1. Model 1: Pollution Permits in an Environment of Constant Returns Technologies

This model looks at how pollution permits should be priced if both the polluting and non-pollution industries use constant returns technologies.

Consider an economy with two groups of final goods: X and Y. The production of good X uses a “dirty” technology such that for each unit of good X produced, a unit of harmful pollutants is emitted. The production of good Y uses a “clean” technology which has zero emissions.

There are L consumers who derive utility from consuming goods X and Y, and suffer from pollution. The representative consumer’s utility function is:
\[ U = x^\alpha y^{1-\alpha} X^{-\gamma^*} \]  (1)

where the \(x\) is the quantity demanded for good \(X\); \(X\) is the total amount of pollutants generated in the production of \(X\); \(y\) is the quantity demanded for good \(Y\); \(\alpha\) is a preference parameter, \(\gamma^*\) is a parameter indicating actual disutility from pollution.

While consumers’ utility is reduced by pollution, each consumer perceives that his/her individual choice has a negligible impact on the level of pollution. Accordingly, the total amount of pollutants \(X\) is taken as given in the consumer’s decision problem.

The representative consumer’s decision problem is:

\[
\text{max } U = x^\alpha y^{1-\alpha} \quad (2)
\]

subject to \(p_x x + p_y y = w + R\)

where \(p_x\) and \(p_y\) are the prices of good \(X\) and good \(Y\); \(w\) is the wage rate normalized to be 1; and \(R\) is a transfer payment from the government’s sale of pollution permits. This payment implicitly assumes that consumers have a right to a clean environment, and a part of that right is sold to the polluter through the government.

Solving problem (2), we have the demand function for goods \(X\) and \(Y\):

\[
x = \frac{\alpha(1+R)}{p_x}, \quad y = \frac{(1-\alpha)(1+R)}{p_y} \quad (3)
\]

We assume the markets for good \(X\) and \(Y\) are perfectly competitive. We further assume that the production of both goods uses constant returns technologies and that labor is the only factor of production. The \(X\)-producing and \(Y\)-producing firms’ decision problems are, respectively:

\[
\text{max } \pi_x = (p_x - r)X - L_x \quad (4)
\]

subject to \(X = a_x L_x\)
\[ \max \pi_y = p_y Y - L_y \]  \hspace{1cm} (5)

subject to \[ Y = a_y L_y \]

where \( a_x, a_y \) are productivity parameters; \( L_x \) and \( L_y \) are labour devoted to the production of good X and good Y, respectively; and \( t \) is the price for pollution permits.

Solving problems (4) and (5), we have the prices for goods X and Y:

\[ p_x = t + \frac{1}{a_x}, \quad p_y = \frac{1}{a_y} \]  \hspace{1cm} (6)

In equilibrium, all goods markets and the labor market clear:

Market for good X: \[ X = Lx \] \hspace{1cm} (7)

Market for good Y: \[ Y = L_y \] \hspace{1cm} (8)

Market for labor: \[ L_x + L_y = L \] \hspace{1cm} (9)

In addition, the total revenue from pollution permits is transferred to consumers:

\[ tX = LR \] \hspace{1cm} (10)

Jointly solving equations (3), (6)-(10), we obtain the equilibrium prices and quantities for the economy. These are presented in Table 1. From the equilibrium quantities, we have the equilibrium actual consumer utility:

\[ U = a_x^{\alpha - \gamma} a_y^{\alpha - \gamma} (1 - \alpha)^{1 - \alpha} [1 + (1 - \alpha) a_t]^{\gamma - 1} [1 + a_t]^{1 - \alpha} \] \hspace{1cm} (11)

The optimal (i.e., utility-maximizing) price for pollution permit can be found by solving the following problem:

\[ \max t \quad U = a_x^{\alpha - \gamma} a_y^{\alpha - \gamma} (1 - \alpha)^{1 - \alpha} [1 + (1 - \alpha) a_t]^{\gamma - 1} [1 + a_t]^{1 - \alpha} \] \hspace{1cm} (12)

The optimal price for pollution permit is

\[ t^* = \frac{\gamma^*}{a_x (\alpha - \gamma^*)} \quad (\text{where } \gamma^* < \alpha) \] \hspace{1cm} (13)
Equation (13) suggests that a negative externality from pollution can be internalized by requiring the polluter to pay for the right to pollute. The optimal price for the pollution right increases with the size of the disutility associated with pollution \((\gamma^*)\).

2.2. Model 2: Pollution permit and technology subsidies under increasing returns

Now we introduce increasing returns to model 1 and investigate whether the presence of increasing returns warrants an additional policy intervention: subsidies to the clean industry which uses increasing returns technologies.

Instead of producing a single good \(Y\) as in model 1, we now assume that the each firm \(i\) \((i=1, 2, \ldots, n)\) in the \(Y\) industry produces a differentiated product \(Y_i\), and the market for the differentiated products is monopolistically competitive. In addition, the production of \(Y_i\) involves a fixed cost \((f_i)\) such that:

\[
Y_i = a_i y_i - f_i
\]  

The existence of a fixed cost means that the production of \(Y_i\) exhibits increasing returns. This model specification of monopolistic competition and fixed costs captures some features of a stylised clean technology industry with intense product competition, and the requirement of fixed product development costs.

With differentiated products \(Y\), the representative consumer’s decision problem becomes:

\[
\max U = x^a y^{1-a}, \quad y = (\sum_i y_i^{\rho})^{\frac{1}{\rho}}
\]  

subject to 
\[
p_x x + \sum_{i=1}^{n} p_{y_i} y_i = w + R - \tau
\]

where \(\tau\) is a lump sum tax used to fund a subsidy to the \(Y\) industry.

Solving problem (15) gives us the demand for good \(X\) and for each variety of good \(Y\):
\[ x = \frac{\alpha(1 + R - \tau)}{p_x}, \quad y_i = \frac{(1 - \alpha)(1 + R - \tau)}{p_{yi}^{1-\rho} \left( \sum_{j=1}^{n} p_{yj}^{\rho-1} \right)} \] (16)

The decision problem of the X-producing firm remains the same as that in model 1, the solution of which gives us:

\[ p_x = t + \frac{1}{a_x} \] (17)

The decision problem of the firm producing Y_i becomes:

\[ \max \quad \pi_{yi} = (p_{yi}(Y_i) + s)Y_i - L_{yi} \] (18)

subject to \( Y_i = a_y L_{yi} - f_i \)

where s is subsidy rate per unit.

Solving problem (18) gives us the price for each variety of good Y:

\[ p_{yi} = \frac{1}{\rho} \left( \frac{1 - sa_{yi}}{a_{yi}} \right) \] (19)

In equilibrium, each firm earns zero profit so that:

\[ \pi_{yi} = (p_{yi}(Y_i) + s)Y_i - L_{yi} = 0 \] (20)

which implies:

\[ Y_i = \frac{\rho f_i}{1 - \rho 1 - sa_{yi}} \] (21)

Assuming that all varieties of good Y are symmetric, we have:

\[ y_i = y_j = \frac{(1 - \alpha)(1 + R - \tau)}{np_y}, \quad p_{yi} = p_{yj} = p_y = \frac{1}{\rho} \left( \frac{1 - sa_y}{a_y} \right), \quad Y_i = Y_j = \frac{\rho f_i}{1 - \rho 1 - sa_{yi}} \] (22)

Also, all markets clear in equilibrium, so we have:

Market for good X: \( X = L_x \) (23)
Markets for each variety of good Y: $Y_i = Ly_i$  

Market for labor: $L + nL_\gamma = L$  

In addition, the total revenue from pollution permits is transferred to consumers:
\[ tX = LR \]  

And total revenue from lump sum tax equals total subsidy
\[ \tau L = nsY \]

Solving the system of equations (16)-(17) and (22)-(26), we obtain the equilibrium prices and quantities for this model, which are presented in Table 1. We also obtain the equilibrium utility level:
\[
U = C(1-\tau) \rho^{-(1-\alpha)\gamma'} (1+ (1-\alpha)a_s t) \rho^{-(1-\alpha)\gamma'} (1+a_s t) \rho (1-\rho a_s)^{\alpha-1} 
\]

where $C = a_x^{a-\gamma} \alpha^{-\gamma} L \rho^{-(1-\gamma)(1-\alpha)} f \rho^{-1-\gamma} a_s^{-\gamma} \rho^{1-\alpha} (1-\alpha)^{\rho-1} \rho (1-\rho)^{\rho}$

Now we first assume that $\tau = s = 0$ in equation (27), then we derive the optimal price for pollution permit is
\[
t^{**} = \frac{\rho \gamma^* + \alpha (1-\rho)}{a_s \rho (\alpha - \gamma^*)} \text{ (where } \gamma^* < \alpha \text{ ) which is greater than } t^* = \frac{\gamma^*}{a_s (\alpha - \gamma^*)}
\]

It can be shown that:
\[
\frac{\partial U}{\partial \tau} \bigg|_{\tau = t^{**}} = 0
\]

where $t^{**} = \frac{\rho \gamma^* + \alpha (1-\rho)}{a_s \rho (\alpha - \gamma^*)}$ and we have used the relation $\tau L = nsY$ which implies

Result (28) means that in a model with both pollution and increasing returns, if pollution permits are priced at a level which is optimal for internalising the negative externality from pollution, individual utility can be increased by an introduction of tax-funded subsidy to the clean industry.
exhibiting increasing returns. In other words, the policy combination of pollution permits and subsidising clean technology outperforms pollution permits alone. Next we consider a different policy combination, namely pollution permits and tax-funded advertising to persuade consumers to switch from pollution generating consumption to “clean” consumption.

2.3. Model 3: Pollution permit and advertising under increasing returns

In model 2 we assume that taxes raised from consumers are used to subsidise the Y industry. In this model, we assume that the tax revenue is instead used by the government to run public advertising campaigns to persuade consumers to switch away from the pollution generating product X (which means more consumption of good Y). Arguably firms in the Y industry can advertise themselves and the government may subsidise such advertisement. However the main purpose of each firm’s advertising would be to persuade consumers to buy the differentiated products of the advertising firm (at the expenses of other competing firms). In contrast, the public advertising aims to win over consumer expenditures from the X industry for the benefit of the Y industry as a whole.

Following Congleton (1986), we assume that consumers’ tastes are given, but public advertising changes consumers’ perceptions. In the absence of public advertising as in model 1 and model 2, consumers perceive that their individual contribution to the pollution problem is negligible, and therefore do not take that into account in their decision making. In contrast, while the consumers’ utility function remains unchanged, advertising changes their perception about their individual contribution to pollution problem and consequently their perceived responsibility to help solve the problem. Thus it is the perceived level of pollution rather than the actual level that features in the utility function which forms the individual’s decision problem.
This treatment may be objected on the basis that consumers’ losses consist of actual damages from pollution. It is of course true that, in the case of air pollution for example, the disutility consists of actual respiratory problems people experience, not the perceived problem attributable to air pollution. However, it is only when people perceive air pollution as a cause of health problems will they take action to reduce air pollution for the purpose of improving health. Thus in the world of imperfect knowledge, people act on the basis of their perceptions which may or may not represent a good understanding of reality. As Hayek (1955) puts it, “most of the objects of social or human action not ‘object facts’ … and cannot at all be defined in physical terms. So far as human actions are concerned the things are what the acting people think they are.” (p.26-27).

We assume that the perceived harm of pollution as a result of consuming good X increases with the amount of advertising expenditure. Since consumers act on the basis of their perceptions, they now take into account the perceived harm of their own contribution to pollution in their consumption choices. The representative consumer’s decision problem becomes:

$$\max U = x^\alpha y^{1-\alpha} X^{-\gamma(A)}, \quad y = (\sum i \gamma_i)^\frac{1}{\rho}$$

subject to

$$p_x x + \sum _{i=1}^n p_x y_i = w + R - \tau$$

where A is tax-funded advertising, $\gamma(A) < \alpha$ is consumer’s perceived harm of pollution.

Since the firms in the Y industry no longer receives a subsidy, their decision problem changes to:

$$\max \pi_{yi} = p_{yi} (Y_i) Y_i - L_{yi}$$

subject to

$$Y_i = a_{yi} L_{yi} - f_i$$

And the zero-profit condition in equilibrium changes to:
\[ \pi_{yi} = p_{yi}(Y_i)Y_i - L_{ni} = 0 \quad (31) \]

In equilibrium, all the revenue from pollution permits are returned to consumers; and the advertising expenditure is fully funded by taxes. The market clearing conditions are the same as those in model 2. We solve model 3 using the same approach as in model 2 and present the equilibrium solutions in Table 1. We also solve the equilibrium utility level:

\[ U = C^\prime[(\alpha - \gamma(\tau L))^{\alpha - \gamma}]^{(1-\gamma)(1-\alpha)} + (1-\alpha) a_it \rho (1+a_it) \rho \quad (32) \]

where \( C^\prime = a_i^{\alpha - \gamma} L \rho (1-\rho)(1-\alpha) \rho f (1-\rho)(1-\alpha) f a_y^\rho \rho^{1-\alpha} (1-\alpha) \rho \)

Now we first assume that \( \tau = 0 \) in equation (32), then we derive the optimal price for pollution permit is

\[ t^{**} = \frac{\rho \gamma^* + \alpha (1-\rho)}{a_i \rho (\alpha - \gamma^*)} \quad (\text{where } \gamma^* < \alpha) \quad \text{which is greater than } t^* = \frac{\gamma^*}{a_i (\alpha - \gamma^*)} \]

From equation (32), it can be shown that:

\[ \frac{\partial U}{\partial \tau} \bigg|_{\tau = 0, t = t^*} = 0 \quad (33) \]

where \( t^{**} = \frac{\rho \gamma^* + \alpha (1-\rho)}{a_i \rho (\alpha - \gamma^*)} \).

Result (33) suggests that in a model with increasing returns, starting from the position where pollution permits are priced at its optimal level to internalize the negative externality of pollution, it is welfare enhancing to introduce a tax-funded advertising campaign to persuade consumers to switch away from pollution generating goods.
3. Conclusion

We have presented in this paper a set of three simple models to study how prices, politics and persuasion may each play a role in environment policymaking in the presence of the negative externality of pollution and the positive externality of increasing returns. Our conclusions are twofold. First, in the absence of increasing returns, requiring the polluting industry to purchase pollution permits can internalize the negative externality of pollution, and the optimal price of pollution permits should increase with the disutility of pollution. Second, with increasing returns in the industry using clean technologies, it is welfare enhancing to complement the pollution permits policy with a tax-funded subsidy to the clean industry, or with a tax-funded public campaign to persuade consumers to move away from the pollution generating goods.

Our results support a basic rule of thumb that where there is more than one source of distortion, more than one policy instrument may be needed to correct them. This is not new as a general result. The novelty of this paper is that it models increasing returns as a source of positive externality together with the negative externality of pollution, and that it considers public advertising as a policy option in combination with pollution permits. In particular, it takes the view that advertising can influence consumer’s perceptions, and since consumers make decisions on the basis of their perceptions, advertising can change behavior without changing tastes.

There are some unresolved issues which need to be addressed in future research. First, while the second model and third model determine an optimal combination of the policies considered, the current model setup makes it hard to explicitly solve for the optimal policy combinations. Second, our models show that introducing either subsidies or advertising can improve welfare, but we have not discussed any potential problems with subsidies and public
advertising, for example, subsidies may not be technology neutral, and advertising may be politically motivated. Thus, what we suggest is that due to multiple sources of externalities, a portfolio of policies (rather than a single policy) should be considered. Future research can be directed to better understanding how an optimal portfolio of policies may be chosen taking into account political economy considerations.

References


Table 1. Equilibrium Solutions

<table>
<thead>
<tr>
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<th>Model 1</th>
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<tbody>
<tr>
<td><strong>Prices</strong></td>
<td>$w = 1, \ p_x = t + \frac{1}{a_x}, \ p_y = \frac{1}{a_y}$</td>
</tr>
<tr>
<td><strong>Quantities</strong></td>
<td>$x = \frac{a_x \alpha}{1 + (1 - \alpha) a_t}, \ y = \frac{a_x (1 - \alpha)(1 + a_t)}{1 + (1 - \alpha) a_t}$</td>
</tr>
<tr>
<td><strong>Utility</strong></td>
<td>$U = a_x^{\alpha - \gamma^<em>} \alpha^{\alpha - \gamma^</em>} L x a_y^{1 - \alpha} (1 - \alpha)^{1 - \alpha} [1 + (1 - \alpha) a_t]^{\gamma - 1} [1 + a_t]^{\gamma - 1}$</td>
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<th>Model 2</th>
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<td><strong>Prices</strong></td>
<td>$w = 1, \ p_x = t + \frac{1}{a_x}, \ p_y = \frac{1}{\rho a_y}$</td>
</tr>
<tr>
<td><strong>Quantities</strong></td>
<td>$x = \frac{\alpha a_x (1 + R - \tau)}{ta_x + 1}, \ y_i = \frac{\rho \ f}{L 1 - \rho 1 - sa_y}$</td>
</tr>
</tbody>
</table>
| **Utility**     | $U = C (1 - \tau) \rho^{1 - \gamma^*} (1 + (1 - \alpha) a_t)^{\rho (1 - \gamma^*)} (1 + a_t)^{\rho (1 - sa_y)^{\gamma - 1}}$  
|                 | where $C \equiv a_x^{\alpha - \gamma^*} \alpha^{\alpha - \gamma^*} L^{\rho} f^{\rho} a_y^{\rho} \rho^{1 - \alpha^*} (1 - \alpha)^{\rho} (1 - \rho)^{\rho}$ |

<table>
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<th>Model 3</th>
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<tr>
<td><strong>Prices</strong></td>
<td>$w = 1, \ p_x = t + \frac{1}{a_x}, \ p_y = \frac{1}{\rho a_y}$</td>
</tr>
</tbody>
</table>
| **Quantities**  | $x = \frac{a_x [\alpha - \gamma (A)](1 + R - \tau)}{[1 - \gamma (A)](a_t + 1)}, \ y_i = \frac{\rho f}{(1 - \rho)L}$  
| **Utility**     | $U = C' (\alpha - \gamma (\tau L))^{\alpha - \gamma^*} [1 - \gamma (\tau L) + (1 - \alpha) a_t]^{-\alpha + \gamma^* - 1} a_t^{\rho (1 - \alpha)} [1 + a_t]^{\rho (1 - \alpha)}$  
|                 | where $C' = a_x^{\alpha - \gamma^*} L^{\rho} (1 - \rho)^{\rho} f^{\rho} a_y^{\rho} \rho^{1 - \alpha^*} (1 - \alpha)^{\rho}$ |