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Environmental impact, quality, and price: Consumer trade-offs and the development of environmentally friendly technologies ☆

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ABSTRACT

The paper examines the effect of heterogeneous consumer trade-offs – between environmental performance, quality of service characteristics, and price – on the generation and diffusion of environmentally benign technology paradigms. We find that the direction, timing, and environmental impact of new paradigms is shaped by the distribution of consumer trade-offs. Of key importance are the initial distributions of consumer preferences, and how those distributions evolve over time. This has serious implications on environmental pollution, and for policy makers seeking to influence the 'greening' of consumer demand.

1. Introduction

What are the implications of the trade-offs we, as consumers, face when choosing between alternative technology products? Do we choose the environmentally cleaner product, even if it offers inferior service quality compared with a more polluting alternative? What happens if the cleaner technology is more expensive than its more polluting rival? Such choices are familiar to us all. As consumers, we face them over a wide range of examples, from purchases involving large ticket items such as cars and holidays, to the everyday purchases we make in supermarkets. Each of us answers these questions in different ways, and our answers have a direct bearing on our individual carbon footprints, and on our collective environmental impact. In other words, heterogeneity of consumer preferences towards trade-offs matter. They have a direct effect on the consumer selections that we make and on the resulting environmental impact of our selections. This is the focus of the current paper.

The paper is a companion to our other paper in this Special Issue. It complements and extends the discussion of how heterogeneous environmental preferences influence the development of cleaner designs within a given paradigm, and paradigm substitutions. By addressing the consequences of heterogeneous consumer attitudes to trade-offs between environmental performance, product quality, and price, this paper enriches and substantially develops the research instigated in the companion paper in this issue.

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The paper is structured in the following way. Section 2 discusses the empirically grounded model that captures a set of stylised facts regarding paradigm substitutions. Using this model, Section 3 investigates the effect of consumer trade-offs on paradigm substitutions and global pollution. First, we examine the effect of differences in mean consumer preferences for environmental performance and direct utility. This enables us to compare, for example, the environmental impact of distributions with a high mean preference for environmental performance and a lower mean preference for the quality of service characteristics, with distributions containing high mean preferences for both environmental performance and service characteristics. Second, we consider the environmental impact of trade-offs between environmental performance and indirect utility (i.e. price). Here we compare distributions with different standard deviations in environmental preferences and in price preferences. Section 4 concludes by bringing together the current set of findings with those established in the companion paper. This enables us to draw a set of broad results on the importance of heterogeneous consumer preferences for the development of environmentally friendly technologies.

2. The model

2.1. Stylised empirical facts in the model

In this section we outline the key features of our empirically grounded model of sequential technology competitions. The model captures a set of stylised empirical facts on pollution, consumption, and paradigm substitutions gleaned from the history of urban transport.[4]

1) *Deep path dependence*. Deep path dependency exists across successive environmental–technological paradigms. This is due to the unfolding of new technological paradigms from old paradigms. While a new paradigm differs from the previous paradigm in some important respects, it also share one or more features. This is reflected in the technology designs themselves.
2) *Environmental promise*. The environmental 'promise' of a new paradigm is an important factor affecting the behaviour of firms and consumers. It was not simply the service characteristics of the car (speed, flexibility, and private consumption) that led to its rapid adoption after WWII. Demand for the car was closely tied to the demand for healthy suburban living, driven by a desire to escape the disease and filth of horse pollution in city centres. Cars enabled the middle class to truly explore a healthier set of consumption opportunities offered by suburban living.
3) *Windows of opportunity*. A pollution minimising design exists within each technology paradigm. Once this design has been identified, no further improvement is possible. As a consequence, pollution steadily increases as consumers continue to buy the technology. Since pollution is a negative externality, continued consumption eventually turns all consumers' utilities negative. This opens a 'window of opportunity' for new, more environmentally benign designs. Consumers are willing to experiment with new technological solutions, and firms have economic incentives to experiment and develop novel technologies that are based on these new scientific/engineering discoveries.
4) *New technology firms*. New technology start-ups champion the new technology. If successful, these start-ups replace the old technology firms to become the dominant industry players. This was the case in the car industry [1], and the importance of new start-ups has been identified in other industries [2].
5) *Consumer preferences affect the timing, direction, and type of innovation*. The direction of intra- and inter-paradigm innovation is driven by the economic rewards to innovative firms. These are strongly influenced by consumer preferences. The decision to develop less polluting designs or, alternatively, designs with high quality service characteristics and/or low price, depends on: (i) a technologically given relationship between alternative combinations of service characteristics and environmental performance (the position of the environmentally optimum design within the paradigm landscape), and (ii) consumers' preferences regarding environmental impact, service characteristics, and price. Heterogeneous environmental preferences were explored in the companion paper. In this paper we examine the relationship between preferences for environmental utility, direct utility (product quality), and indirect utility (price).

Our model differs to other well-known models of sequential technology competitions, such as [3] and [4]. First the adoption, development and diffusion of new technology paradigms are endogenous within the model. The 'window of opportunity' is operationalised in the following way. An environmental–technology paradigm is modelled as a pseudo-NK landscape. Within each paradigm there exists an optimal global peak. This is the design that combines minimum environmental impact with a relatively high product quality and low price. Once identified, no further improvements can be made with respect to environmental pollution within the paradigm. If global pollution continues to rise over time, consumers have a real incentive to experiment with new, less polluting technology paradigms. Once the limits of pollution improvement have been reached – i.e. once the optimal design of an existing paradigm has been identified – the search begins for a more environmentally friendly technology, based on the latest scientific/engineering breakthroughs. New start-ups firms develop the commercial applications of these breakthroughs.

Second, Malerba et al. *et al.* treat quality as a simple integer value. We unpack performance quality, using the Lancaster [5] service characteristics approach, into a vector of service characteristics $\vec{x}$. This vector contains a set of complex, non-linear relationships between service characteristics. Perceived quality depends on the valuations that are placed on these service

[4] See the companion paper in this Special Issue for a detailed discussion.