Co-evolution of capabilities and preferences in the adoption of new technologies

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Abstract. *The objective of this paper is to propose a multidisciplinary approach for the analysis of demand and innovation. It combines insights from studies on technology diffusion, evolutionary economics and cognitive psychology to argue that consumption and demand are learning processes driven by trial-and-error, rather than by ex-ante maximization. The paper presents a heuristic synthesis to incorporate learning processes in the determination of consumption preferences and capabilities. The case of banking service innovation in the UK is presented as an illustrative example of the outlined dynamics.*

1. Introduction

The purpose of this paper is to explore the relationship between final demand and innovation. Let us begin with an observation: the standard analysis of technological change in the economics and management literatures is often restrained to the supply side, and looks mainly at the introduction of new products and services or at the modifications that can be implemented in the production process. Yet new products and services open up new opportunities to final users and stimulate learning processes as well as changes in consumption habits. In turn, such demand dynamics yield practical feedback for the design of specific types of final goods. Of particular interest is the case of information-based products, like services, in which growing adherence to the 'open innovation' model has displaced the canons of production and provision so that users' first-hand experience, combined with observed trends of adoption, can be absorbed in the design through incremental customization.

While concrete examples may spring readily to mind, the received analytical views offer a rather limited account of these phenomena. According to the standard economic approach new or improved technologies spread tout-court across perfectly-informed and fully rational agents. Yet seminal works – by Rosenberg[1] among others – show that the take-up of new innovations is slow and that rates of acceptance are uneven, both across technologies and adopters of the same technology. Empirical studies ascribe these features to both supply- and demand-side characteristics of the adopting environment: attitudes towards change and emerging opportunities due to new technologies, it is argued, depend on the uncertain and, to some extent, unpredictable process of knowledge growth.

These observations do not fit the picture proposed by the standard economic approach in which consumption is merely the result of an exercise of optimal allocation, and in which consumers are but atomistic rational agents who follow *ex-ante* rules. This paper argues that such a framework proffers limited understanding of the dynamics of demand. For one, it does not explain how preferences develop and change over time; second, it overlooks how preferences translate into actual consumption choices; third, the consolidated notion of consumers as passive actors is in open contradiction with a growing array of instances in which user-producer interactions crucially affect the design of products and services.

The objective of the paper is to cast the analysis of demand and innovation under a new light. It will focus on the behavioural determinants of decision-making by bringing together scholarly work developed independently in the economics of technological change and in cognitive psychology.[2] The ensuing framework integrates typical elements of innovation studies – like the growth of knowledge and the associated learning mechanisms: the main conjecture is that consumption and demand are evolutionary processes driven by trial-and-error, rather than by *ex-ante* maximization. Decision-making is understood as a cognitive process, and framed in what Austrian economists call 'real' (or historical) time. In this view the availability of new technologies triggers decision processes driven by *exploratory* activities – i.e. searching, evaluating and selecting options – and *coordination* activities – i.e. either complementing or substituting present consumption routines.

We believe that such themes are germane to researchers and practitioners alike. On the one hand uncovering the behavioural processes stimulated by innovation is a staple of economists and scholars of technology management. On the other hand, managers and inventors strive to understand how consumption routines develop and, in turn, stimulate users to engage with new technologies. The paper is organized as follows. The next section is divided in two parts. The first presents a critical review of the orthodox economic approach to consumption. In the second part alternative approaches are outlined drawing from studies on the diffusion of innovation, evolutionary approaches and cognitive psychology. These ingredients are blended in the third section to elaborate a heuristic synthesis for the analysis of demand and innovation. Section four presents an illustrative example of adoption of automated banking services in the United Kingdom (UK). Conclusions recap the key insights, namely: i) repeated use of information technology engenders *ex-post* learning effects; ii) the existence of switching costs have a direct bearing on consumers' decision to either adopt or not new technologies; and iii) the development of capabilities through consumption experience determines endogenously new preferences and future demand patterns alike.

2. Innovation and demand: an overview of the literature

This section provides a review and a commentary on scholarly research on consumer analysis, and is organized in two steps. It begins with the orthodox economics view and continues in the second part with alternative approaches elaborated in the context of studies on technological change and on cognitive psychology.

2.1 – Orthodox economic approaches to the analysis of consumption

The standard microeconomics approach to the analysis of consumer choice includes the following ingredients:

1. A set of alternatives: consumption set X;
2. A system of preference relations represented by a utility function: $x \geq y \Leftrightarrow u(x) \geq u(y)$;
3. A budget set: $B \subset X$;
4. A set of behavioural assumptions: Preference (i.e. Utility) maximization;

As the recipe has it, fully rational agents solve the optimization problem by picking out of the consumption set a single good, or a bundle, which (i) maximizes the utility function; (ii) is coherent with the prescribed preferences, and (iii) is compatible with the budget constrain, not simply in the sense that ends are met but also that available resources are always fully employed. Building on these foundations, eminent economists have refined the formal analysis of this static optimization problem, and of the solutions it entails. At the same time however they overlook important determinants of the decision-making process that underpins consumption. In fact, the axioms of full rationality and perfect information minimize the role of cognitive processes such as learning. Furthermore in this approach economic action is detached from the contingency of time and place and is thus time-invariant. Even when 'time' is accounted for, under the standard assumptions the analysis generates puzzling results. To clarify these points we briefly overview three standard economic models that deal with consumer behaviour.

In macroeconomic Ramsey-Koopmans models of optimal growth consumption is instrumental to determine long-run savings, investments and, hence, the steady-state path. The dynamic element of such an approach is the incorporation of intertemporal consumption levels – rather than choices – in the paths of long-run growth. Thereby the consumer is but an instantiation of the archetypal rational agent who re-allocates his endowment at the beginning of each period on the basis of modified expectations over income and prices.

Another widely-known framework of reference is the microeconomic analysis of Gary Becker, which treats consumption as a form of production that uses goods and time as inputs.[3] The aim is to determine the efficient allocation through the paradigm of individual utility maximization constrained by income and various types of capital stocks, including human capital. Two features are worth emphasizing. The baseline model is labeled dynamic on the grounds that this particular form of production is repeated over a number of periods. However, because this takes place in chronological rather than historical time very little can be inferred on how consumers' preferences are determined. Furthermore, and related to the former, tastes are embedded in 'meta-stable' utility functions that are assumed invariant both over time and across individuals.[4] In other words, the hypothesis of a homogenous population of fully rational agents with perfect information makes interpersonal differences in tastes superfluous.

In recent years it has been pointed out that even the treatment proposed by Lancaster[5], advocated by many as a model that overcomes the outlined shortcomings and succeeds in opening consumption analysis to the element of innovation, is missing two important points. First, preferences are exogenous. The implication is that the renowned product characteristics underpinning the 'production of consumption' follow rules that are given *ex-ante* and assumed to be perfectly known to individuals. Loasby advances another important critique to the Lancastrian model: as behavioural rules are disconnected from learning and experience consumers thus portrayed do not engage in the act of discovery, which is instead a quintessential element of any innovation process.[6]

Two common features across the outlined models are worthy of attention. First, the standard hypothesis is that economic agents are always endowed with full knowledge of the goods that are available for consumption, and with adequate skills to use them and derive utility. On these grounds the canons of static allocation restrict the role of economic agents to that of mere executors of ready-made instructions. Second, the 'dynamic' label in these models is used to indicate that the traditional static allocation mechanism extends over a longer time-horizon. The latter is achieved through the artifice of assimilating time to a metric space – which Austrian economists O'Driscoll and Rizzo appropriately call 'spatialized' time, as opposed to historical 'real' time. [7] Therefore complications due, for example, to interdependence among consumption choices can be avoided by assuming additive and separable utility functions, and optimal consumption levels determined exogenously via a parametric treatment.

This approach arguably proffers a notion of decision-making as mechanical, as opposed to intentional. In fact, as consumers' choices are time-invariant the analysis cannot account for the effects of past experience. In this paper we propose a specification of the problem which is grounded on a different metric for time – in the words of Marshall "the source of many of the greatest difficulties in economics" [8] and which allows for explicit integration of the dynamics of knowledge and of the associated learning mechanisms. This point will be further developed in the third section. Let us now take an intermediary step and overview the range of perspectives elaborated in alternative approaches to the analysis of demand.

2.2 – Alternative views for the analysis of demand and innovation

The dissatisfaction with the inherited approach to the analysis of decision-making elaborated in economics has fuelled widespread criticism. In this section we review three strands of literature that contributed to new understanding of the dynamics of consumption and demand.

Studies on technology adoption focus on the take-up of 'new' products or processes, whereby the notion of novelty relates to either 'previously unavailable' or to the context of use. By and large empirical observations show that the take-up of innovations behaves differently from what the orthodox approach would suggest: adoption is gradual and rates of acceptance are uneven both across technologies and adopters of the same technology. Such phenomena are ascribed to changes in the adopting environment as experiments with new technologies, in both the supply- and the demand-side, trigger learning effects. Technology adoption is thus understood as an emerging process driven by problem-solving activities whose effects are commonly synthesized by a sigmoid-shaped curve.

Griliches first proposed the 'epidemic contagion' framework to analyse technology adoption in a population of heterogeneous agents characterized by information asymmetries and bounded rationality. The emerging path, he argued, reflects the dispersion of information about the effective profitability of adoption. Mansfield further contributed to the notion that the diffusion path reflects a sequence of adoption lags determined by the characteristics of the information available in the environment. Further down this path, David and Metcalfe associated heterogeneity of potential adopters to their cost conditions and came up with the path-breaking proposition that the adoption process stems from the creation of complementarities across families of related technologies. This view hinges on the notion that the growth of knowledge is embodied in the changing characteristics of the technologies, as opposed to previous studies focused on a static view of technologies (i.e. given and unchanging). More recently Antonelli enriched the analysis by articulating the notion and the impact of search costs on the adoption of intermediate inputs under assumptions of asymmetric information and bounded rationality.[9]

Several common threads emerging across the aforementioned works are relevant to the remit of this paper. First, it is unanimously advocated that the take-up of new products cannot be associated to passive attitude but instead requires the active participation of prospective users: the latter need to engage with dedicated activities such as search, evaluation, selection, adaptation and integration. A second important element is the role of network externalities whereby the probability of adoption of new technologies is related to the number of existing users. Notably, this rule is not invariant and externalities can be positive up to a critical level and then negative due to phenomena like congestion. A dynamic reading of externalities implies another feature common across the studies on diffusion: the growth in the population of adopters is likely to be matched by greater variance in their characteristics like, for example, attitudes to change. The distribution of such characteristics, in turn, can be ascribed to a combination of factors. When the variance is determined by social and demographic stratification mature technologies are likely to undergo segmentation and their supply to be characterised by groups of partially overlapping products. These works also reaffirm the notion of technology diffusion as a historical process, and emphasize that learning processes are contingent to specific circumstances that can either facilitate or hinder the emergence of new technologies. In fact as the evolution of the stocks of technologies generates interdependency in both production and use, the structure of past vintages impinges upon the decision of whether to adopt or not new technologies – both for suppliers and consumers. In this context costs associated to learning together with the adoption of new routines are especially relevant and consumption opportunities can be thwarted by resource capacity, especially when time constraints are considered.[10]

The insights proffered by empirical studies on technology adoption have been recently articulated in the context of evolutionary economics. Building on axioms of bounded rationality and imperfect knowledge, evolutionary scholars argue that differential behaviour and environmental pressure impinge upon the rate and direction of economic development. This approach to economic agency is based on the juxtaposition of two complementary dimensions of analysis. At individual level, agents organize information to design and implement separate decision rules and courses of action. At the same time, because it implies the use of individual experience, this process generates variety in populations of economic agents thus giving way to a collective process of specification of selection criteria.

Scholars like Bianchi, Langlois and Cosgel and Loasby apply these notions to the analysis of consumption.[11] Consumers, they argue, are active contributors to the innovation process, and operate as learning agents who engage with exploration and coordination activities. These works share similar understanding with the present paper on two counts. First, they appreciate that technological progress instills substantive and procedural uncertainty in any system, either of production or consumption. Second, they emphasize that economic agents deal with such uncertainty by developing cognitive processes that are tied to specific circumstances.

A recent and pertinent proposition for the study of consumption has been put forth also in the field of experimental psychology. According to Hernnstein and Prelec consumers behave according to the 'melioration hypothesis', which can be synthesized by two rules of thumb: [12]

1) Consumers value the average satisfaction received per unit of investment in each activity;
2) Consumers shift behaviours as soon as an alternative activity yields higher returns.

The melioration hypothesis does not ensure automatically that the choice of consumption is optimal (at least in the orthodox sense) but rather guarantees consistency over time and across complementary consumption activities. This view introduces two important elements in the analysis of demand: first, experience accumulated over time shapes the way in which consumers develop preferences and capabilities; second, consumption is now seen as a set of interdependent activities.

Let us summarize the main points emerged so far. The first part of the section proposed a critical assessment of the foundations that underpin the orthodox economic view, and highlighted a number of shortcomings associated with this particular approach to demand and innovation. In the second part we explored alternative theories including studies on technology adoption, evolutionary views of economic change and recent insights from experimental psychology. Our conjecture is that the great divide between the mainstream approach and the alternative ones is a conceptual gap concerning whether, and how, the dynamics of knowledge growth are included in the analytical apparatus. Innovation studies, we argue, propose a more nuanced view of economic change in which consumers play an active role and which is consistent with empirical observations on technology adoption. The next section will blend ingredients from these views to elaborate a framework for the analysis of demand and innovation that accounts for the growth of knowledge and the associated learning processes.

3. A framework for the analysis of demand and innovation

3.1 – Building blocks: time, structure and the growth of knowledge

Research on innovation and technological change postulates that imperfect knowledge and bounded rationality are defining characteristics of any economic system. In this tenet the need to confront both procedural and substantive uncertainty keeps agents alert to the necessity of change through the design and modification of plans, or the search and evaluation of alternatives. Unlike static theories of decision-making grounded on the mere use of existing endowments – including information – competence-based approaches focus on the combined accumulation of resources and development of solution rules. This perspective shifts attention away from the virtues of objective rationality and warrants the opportunity to articulate the notion of 'choice' in terms of discovery process driven by learning and problem-solving.[13]

The majority of contributions in this tradition explore such themes in relation to production and supply. We propose to bring the analysis of consumption and demand in this conceptual terrain. Accordingly, our working hypotheses are: i) consumption takes place in historical time; and ii) its constituent activities are organized according to some kind of structure.

In the orthodox approach consumption is looked at in terms of discrete events, and much of the emphasis goes towards the conditions underpinning the instantaneous purchase of goods. Such a view clearly overlooks the process that creates those conditions, and implicitly denies that consumption is the outcome of intentional decision-making based on learning. As elapsed time does not affect memory and experience, *a fortiori* the rules that determine consumption patterns are time-invariant. Austrian economists argue the opposite: time-elapse is an individual experience whose constituent events are processed through the construction of cognitive mechanisms.[14] Similar to innovation studies, the growth of knowledge is understood as an individual process shaped by distinctive features of the time and the place. Extending this view to the analysis of consumption implies the following

> ***Proposition one:*** *Consumers are boundedly rational agents and deal with uncertainty by developing skills and decision rules. The associated learning processes are not time-invariant, but rather contingent to the circumstances in which consumers operate.*

The connection between time and knowledge is a hinge of the Austrian approach, which emphasizes the processes that facilitate the absorption of experience and stimulate individuals to engage with new courses of action. While in the orthodox tenet agents are always endowed with know-what and know-how to consume, in the view proposed here consumption choices are an outcome of knowledge accumulation and use. Similar to Loasby, we posit that such discovery processes impinge upon what and, most importantly, how individuals learn.

The inclusion of experience implies the adoption of historical, 'real' time as a frame of reference for the analysis of intertemporal decision-making. This specification accounts for acquisition and elaboration of information through memory and intentional planning. From this it follows that the agency problem thus defined is one of development rather than of allocation. In fact, learning processes trigger the embodiment of past experience into consumption routines which are subject to *ex-post* evaluation, as opposed to *ex-ante* maximization typical of the orthodox view. We suggest that the implementation of such routines in courses of action stimulates consumers to elaborate individual frames of reference. This leads to

> ***Proposition two:*** *the organization of consumption activities in real time responds to functional structures which are implemented intentionally, and evolve over time as a result of learning.*

The structure we refer to is the outcome of a cognitive process which draws on and, in turn, impinges on the interlocking of various consumption activities. Accordingly, changes in consumption plans reflect the reorganization of such activities rather than substitution among goods within a bundle. This idea shares commonalities with the understanding of economic agency proffered by Menger.[15] Consumption, he argued, is made of constituent activities, namely: identification of needs, search for means to satisfy them, selection of feasible options, purchase and use of goods and services, and an *ex-post* assessment of the chosen option which will, plausibly, affect future consumption. Menger also argued that cognitive processes for the acquisition and use information are necessary in dealing with inherently uncertain, prone to error, and time-consuming economic processes. The construction of causal connections among goods is a consequence of such cognitive processes. In the ensuing view consumption activities connect past experience (i.e. memory) with future courses of action (i.e. planning). Such activities, in turn, are characterized by dynamic complementarities that guarantee intertemporal consistency among the constituent activities of consumption.

This idea bears similarities with the argument proposed by Langlois and Cosgel whereby consumption activities are characterized by form of functional hierarchy.[16] Their notion of hierarchy echoes the Mengerian ordering of goods according to typologies of needs: first order goods (i.e., "the bread we eat"), second order goods (i.e., "the flour from which we make the bread") and so forth (i.e., "the grain that we mill into flour"). As hinted before, hierarchy, ordering, and structure are dynamic concepts: having goods at one's disposal to either transform them in higher order goods (i.e. flour into bread) or gain utility from them (i.e. eating bread), implies the growth of knowledge and the development of skills and experience.[17]

So far the section has outlined the building blocks of an alternative approach to the analysis of demand. In the remainder we present a heuristic synthesis of the propositions presented above.

3.2 – Demand and innovation: a heuristic synthesis

Let us begin with a cautionary remark. The heuristic presented seeks to explore promising new avenues for the analysis of consumption which resonate with the conceptual terrain discussed before.[18] This empirically-informed exercise is purposefully circumscribed to a number of specific instances rather than being a full-fledged formal synthesis. It reflects back on some points raised in the opening section and applies to innovations that affect the infrastructure of information-based products like services. In the baseline case considered here consumers confront the decision of whether to adopt new technologies and undertake associated activities, or to retain existing ones. The remainder of the section explores the mechanisms underpinning the associated decision-making process. The case of innovation in retail banking discussed in the next section provides an illustrative example.

Consider a utility function associated to a set of N activities q_i weighted by an individual value function v_i which depends on the distribution of all consumption activities: [19]

$$U = \Sigma\, q_i\, v_i(q_i) \qquad , (i \in N) \tag{1}$$

Under the hypothesis of bounded rationality, and consistent with the melioration hypothesis, agents evaluate the average value v_i of each activity instead of the marginal value. This is weighed up by costs c due to learning as well as search for alternatives:

$$q_i = f_i\ [\, c_{i1},\, c_{i2},\, \ldots,\, c_M\, ,\, c_N\ (n_{i1},\, n_{i2},\, \ldots,\, n_M\, ,\, n_N\, ;\, s_{i1},\, s_{i2},\, \ldots,\, s_M\, ,\, s_N)] \tag{1'}$$

The value is determined by characteristics which are both shared with other activities (capital subscript in the formula) as well as distinctive (small subscript). Cost levels c depend on the number of times n that a certain activity is undertaken – contributing to the accumulation of experience – and on indirect effects s like, for example, sharing experience within the community of consumers. We consider the case in which agents engage with new technologies that are time-saving like, for example, newly available automated – as opposed to traditional paper-based – retail payment services.

The conjecture is that each user allocates a fixed total amount of time T time among partially complementary activities:

$$T \geq q_0\, t_0 + q_1\, (t_1\, (c_1\,)) \tag{2}$$

with T no smaller than the overall time opportunity cost associated with each of the alternative activities; t_i is the opportunity cost relative to time consumption of activity i; q_i the units of activity i, and $c_{j \neq I}$ the additional cost of learning new activities. The constraint in equation (2) indicates a functional relationship between time dedicated to the existing technology and the costs associated to the adoption of the new one.

Figure 1 shows the trade-off between the incumbent technology 0 and the new technology 1. Consistent with the framework outlined before, the degree of engagement with these and the subsequent time allocation depends on the cost associated with their use. In the example of banking consider the case in which two technologies are available, and the incumbent one (i.e. human teller) has a constant marginal cost while the new one (i.e. automated machines) features decreasing marginal cost to use. In this case time allocation tips in favour of the incumbent technology *ht* until the marginal cost relative to the new one reaches a critical level of intensity of use, say threshold n^*. Above this level consumers will switch to the new technology *am*. The general rule is: $t_i > t_j \Rightarrow q_i < q_j$ $(i, j = 0,1; i \neq j)$.

FIGURE ONE ABOUT HERE

The vertical distance between the time-constraint limit T and the lowest marginal "cost of use" curves determines the composition of the consumption bundle. Two observations are in order at this point. First, the critical value of *n* is a proxy for the cost of learning *c* as in equation (1'), hence it will also depend on the shared inputs of knowledge *s*: n^* will differ across consumers since the composition of the activities varies with the inputs *s*. Second, the vertical dotted line at the end of the time opportunity marginal cost represents the instance in which a large number of consumers $n^\wedge$ adopt the new technology and creates congestion effects.[20] The combined effect of these two forces affects the rate of substitution between the two activities in such a way that differential opportunity cost, expressed in time units, yields a non-linear budget constraint.

Figure 2 shows the time budget line kinked at q^*_1, corresponding to a critical level of use of the technology which yields positive returns. With no learning effects the constraint would have been linear, and the highest feasible indifference curves lower (i.e. u_0).

FIGURE TWO ABOUT HERE

Summing up, learning effects due to availability of new technologies generate local efficiency gains in consumption. The costs of learning depend on the average values that consumers assign to the technologies available: this reflects the circumstance that each activity requires the allocation of a portion of time for the organization of individual consumption. At the same time, it resonates with the notion that sharing knowledge within community of consumers yields some form of externality.[21] The speed of substitution between the incumbent and the new technology depends on the benefits generated by learning effects.[22] In this view coexistence between complementary technologies – as opposed to the scenario of a radical switch – is a likely outcome of the gradual process of technology substitution.

Let us now apply this baseline model to the case of intertemporal decision-making in a context of bounded rationality and uncertainty that is consistent with the conceptual background outlined before. As already discussed, the melioration hypothesis postulates that consumers distribute their time endowment among a range of alternatives, and that such decisions are weighted by the average reward they associate to each activity. Thereby coexistence of more activities within the consumption bundle implies that their average rewards $v_{i,\,j}\ (q_{i,j})_{\ i\neq j}$ are equal. In presence of the time constraint, it will be

$$v_0(q_0)= v_1(q_1) \tag{3}$$

$$\alpha_0\, q_0\, +\, \alpha_1\, q_1 = 1 \tag{4}$$

where $\alpha_i\, =\, t_i\, /\, T$ is the proportion of time budget that is allocated to activity i. The underlying principle is that as the average reward of an activity increases, so does its share in the consumption bundle. This kind of dynamic is carried over time by a mechanism of intertemporal substitution among activities which is synthesized by means of a replicator dynamics equation. This accounts for time allocation across activities $z_i=\alpha_i\, q_i$

$$\frac{dz_i}{dt} = \gamma\, z_i \left\{ v_i\left(\frac{z_i}{\alpha_i}\right) - \bar{v}\left(\frac{z_i}{\alpha_i}\right) \right\} \tag{5}$$

where $\bar{v}(\, z_i\,)=\Sigma\, z_i\, v_i\, (z_i)$ and γ is a rate coefficient. Equation (5) embodies the trial-and-error mechanism that determines the share of each consumption activity over time. Thereby the relative importance of each changes depending on the distance from the average value of all activities. This implies that as time goes by learning and experience alter the structure of consumption when new activities yield higher returns. In particular, when the average reward associated with an activity is systematically higher than the others, preference towards the latter grows in relative importance across the consumption bundle. The practical implication is that developing preferences for a new technology depends ultimately on repeated use, and on how learning conditions facilitate or hinder competence building.

Continuing with the heuristic, decreasing marginal costs associated to the use of the new technology yield a lower proportion of time budget for activity 1, α_1 in equation (4). Accordingly, positive feedbacks increase the average reward of activity z_1. This can be expressed in terms of equations (3) and (4), where the derivative of the value function is denoted as $\partial v_i / \partial x_i = v'$, and will be:

$$\begin{pmatrix} v'_0 & -v'_1 \\ \alpha_0 & \alpha_1 \end{pmatrix} \begin{pmatrix} dq_0 \\ dq_1 \end{pmatrix} = \begin{pmatrix} 0 \\ -q_1 d\alpha_1 \end{pmatrix} \quad (6)$$

Decreasing costs associated to new activities induce reinforcement of z_1 , with the signs of the derivatives reflecting changes in activity levels relative to α_1:

$$d\, q_0 / d\, \alpha_1 = -\,(q_1\, v'_1 / \Delta) < 0 \quad (7a)$$

$$d\, q_1 / d\, \alpha_1 = (q_1\, v'_0 / \Delta) > 0 \quad (7b)$$

where $\Delta = (v'_0\ \alpha_1 + v'_1 \alpha_0) > 0$ is the determinant of the system.

Reinforcement effects in the demand for a particular technology are thus the combined outcome of individual learning and of interaction with other users. Preference formation in this framework is endogenized via learning and capability-building which, in turn, determine the returns of each consumption activity.

4. An illustrative example: retail banking innovation in UK

Let us now provide the illustrative example of retail banking innovation in the United Kingdom (UK). This is an interesting case of industry evolution which originates in 1960s following the widespread adoption of new information and communication technologies (ICTs) and whose effects cut across various layers of the industry structure. The most evident changes include (i) a growing degree of specialization and diversification in the supply chain; (ii) the emergence of new, both intended and not-, patterns of provision and of use of payment services; (iii) the development of a new regulatory framework. The evolution of the retail banking industry has been interpreted as a distributed innovation process, enabled by the opportunities opened up by new technologies but ultimately achieved through a collective transformation of the knowledge base of service suppliers, users and regulatory institutions. [23] Yet, as it is often the case, much has been said on the supply-side while the role of demand remains in the background.

The core business of retail payments is the management of a large volume of small-value transactions. We focus on the plethora of automated services that facilitate access to such transactions: in particular, plastic (debit or credit) cards, which were introduced to replace cheques and cash payments, and Automated Teller Machines (ATMs), which represent an alternative to visiting brick-and-mortar branches for cash withdrawal and information retrieval. Table one provides the breakdown of retail expenditure in percentage terms by payment method in the UK between 1990 and 2003 (Source: APACS).

TABLE ONE ABOUT HERE

A look at these patterns of use indicates clearly that the acceptance of automated banking services has grown slowly but gradually: despite alternatives being available since the end of the 1980s cash payments still accounted for 65% of overall retail transactions in 2003 (79% in 1990). In fact, automated services outgrew paper-based ones only in year 2000. Among non-cash payments we observe the resilience of standing orders (paper-based), and the fast growth of plastic cards as a substitute to cheques.

Figures on the use of ATMs (Automated Teller Machines) technology provide broadly similar indications. The ATM was designed to replace human tellers within the branches. The first version of the machine was a simple cash-dispensing device which was usually, albeit not exclusively, deployed in the vicinity of the premises of a branch. Despite the core function has not changed from its inception, the technical platform has evolved significantly. Scholarly research[24] on the transformation of the UK banking industry draws attention to the combined effect of two processes: (i) the centralization of information-processing which has evolved from highly dispersed proprietary systems to the current architecture shared by all major UK financial institutions through the LINK hub; (ii) the transformation of service delivery characterized by a spurt of front-end technologies and the associated variety in the service mix. The technology underpinning the ATM has evolved across various generations of machines and of system architectures:

- ATM1 (1975-circa 1985): Cash-only dispensers; each bank uses proprietary machines;
- ATM2 (1986-circa 1996): New machines providing complementary services; growth of machine sharing across financial institutions;
- ATM3 : (1997- to date): machines connected to Internet (financial kiosks); total machine sharing through the LINK circuit.

Figure 3 offers an interesting indication on the co-evolution between the interface of the ATM and the patterns of demand for banking services: the growing capacity of the ATM contrasts with the slow shrinkage of the circuit of traditional brick-and-mortar branches. Moreover, we note that the pattern of diffusion of ATMs resembles a threefold family of S-shaped curves linked in correspondence of where the older curve approaches saturation – when new ATMs were introduced in 1985 and 1996.

FIGURE THREE ABOUT HERE

A similar movement is shown in Figure 4 with pattern of actual used capacity of the ATM network presenting a threefold S-shaped curve. As it can be observed the curves meet in correspondence of the transition from ATM1 to ATM2, and from ATM2 to ATM3 (clearly, use lags of a couple of years behind the introduction of the new machines).

FIGURE FOUR ABOUT HERE

The evolution of retail payment systems is typically driven by indirect externalities which effectively determine the success or the failure of this kind of network-based technologies. Therefore, as more consumers use a payment platform banks have the incentive to invest in its development and merchants to join it. In turn, the expected returns to investments in a specific payment instrument increase with the size of the network of suppliers. Our conjecture is that heterogeneity across customers plays a relevant role in this kind of industry dynamics. As Chiesa and Manzini point out, oversight of diversity across their learning attitudes is a prerequisite for poor returns from investments in ICTs in the banking sector.[25] In fact strategic management has only recently begun to address this issue by adapting the design of large information-based systems to observed patterns of use. The ultimate goal is to capture different groups of users, and to balance their diverse needs and abilities.

Interestingly, the history of UK banking shows that distributed learning processes are major drivers for new forms of competition among payment platforms.[26]

Reflecting back on conceptual issues at stake, we find that both the evidence and the interpretative analysis proposed here do not fit the purpose and the logic of the orthodox economic approach, according to which representative agents opt at once for the consumption activity that yields the highest utility level. While this is consistent with the postulate that consumers are endowed at any time with all the necessary knowledge, it contrasts with empirical studies on technology diffusion. Moreover, resilience of established consumption habits as observed in the case of banking highlights a flaw also in the postulate that consumption is merely a sequence of discrete purchases. In contrast, the heuristic presented in the third section builds upon the notions of real-time and of structure to invoke the idea of consumption trajectories as intertemporal processes of problem-solving. By and large, it has been argued, such processes unfold in a context of uncertainty and bounded rationality: their effects are thus gradual and contingent to the degree of engagement with new technologies and the associated consumption activities.

We argue that such kind of heuristic represents a step towards a more nuanced approach in which learning and experience play an active role in the analysis of demand. Certainly, it resonates well with the key message proffered by studies on technology diffusion.[27] To reiterate, diffusion patterns are an outcome of incremental substitutions among technologies: as the process is distributed over time and across actors the evolution of technology design is a consequence of dual learning among suppliers and users alike.

5. Concluding remarks

This paper has sought to provide a heuristic approach to the analysis of demand and innovation. The perspective developed here frames the theory of economic agency in historical (or real) time and integrates the axioms of bounded rationality and uncertainty, as opposed to perfect information. In this perspective the growth knowledge through learning and experience is pivotal for the organization and implementation of decision-making processes.

The paper has argued that these notions are germane to the study of consumer behaviour at least as much as to that of production and supply. It has interpreted the relationship between demand and innovation as the endogenous outcome of a co-evolutionary process between consumption capabilities and preferences. The heuristic proposed in the third section shows that consumption plans are the outcome of specific design shaped by a combination of experience, experimentation and the effects of social interaction.[28] Furthermore, it was argued, the component activities of consumption respond functionally to a structure which is the result of intentional efforts to organize consumption in real time on the basis of previous experience. The paper has looked at the take-up of small payment technologies in the UK banking system as illustrative example. From this emerges that repeated use of information technology engenders ex-post learning effects and that the adoption of new technologies is thwarted by the existence of switching costs.

The heuristic proposed here defines the contours of an analytical approach that accounts for these features vis-à-vis the illustrative example of banking: this method could be extended to a number of other case studies characterized by growing variety of consumption choices, provided that empirical evidence on consumption patterns is available. Clearly the case of electronic banking is but one instance of how new technologies stimulate new practices of use. At the same time demand for banking services differs from, say, demand for entertainment in that it lacks the leisure dimension. Future research willing to incorporate these ingredients would have to go further down the road of psychological and sociological based approaches to the analysis of consumption.

Framed in a broader picture the paper restates the notion that innovation generates new opportunities and constraints: thus, the extent of its success is ultimately contingent on learning conditions and adaptive behaviours across both producers and consumers. In turn, a proper grasp of how the emergence and transformation of behavioural patterns impinge upon the innovation process is not just the preserve of theoretically-concerned scholars, but bears practical relevance for managers and policy-makers alike.

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18. The heuristic covers some points recently discussed in F. Malerba, Innovation and the dynamics and evolution of industries: Progress and challenges, *International Journal of Industrial Organization* 25, 2007, 675-699.

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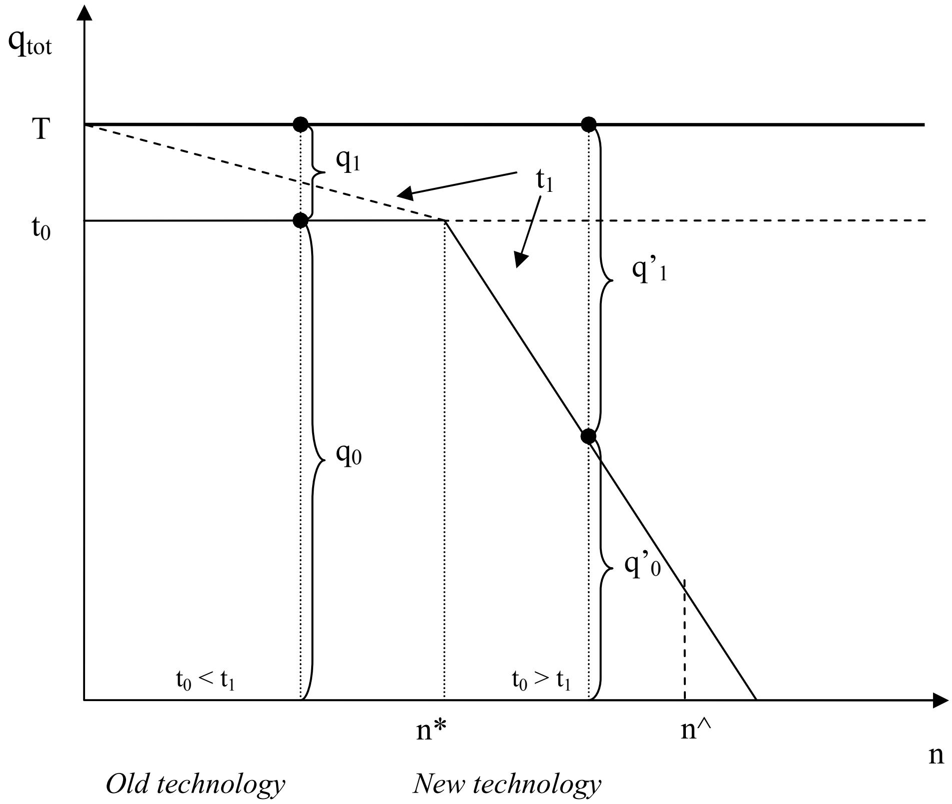


Figure 1 – Allocation of activities within the time budget constraint

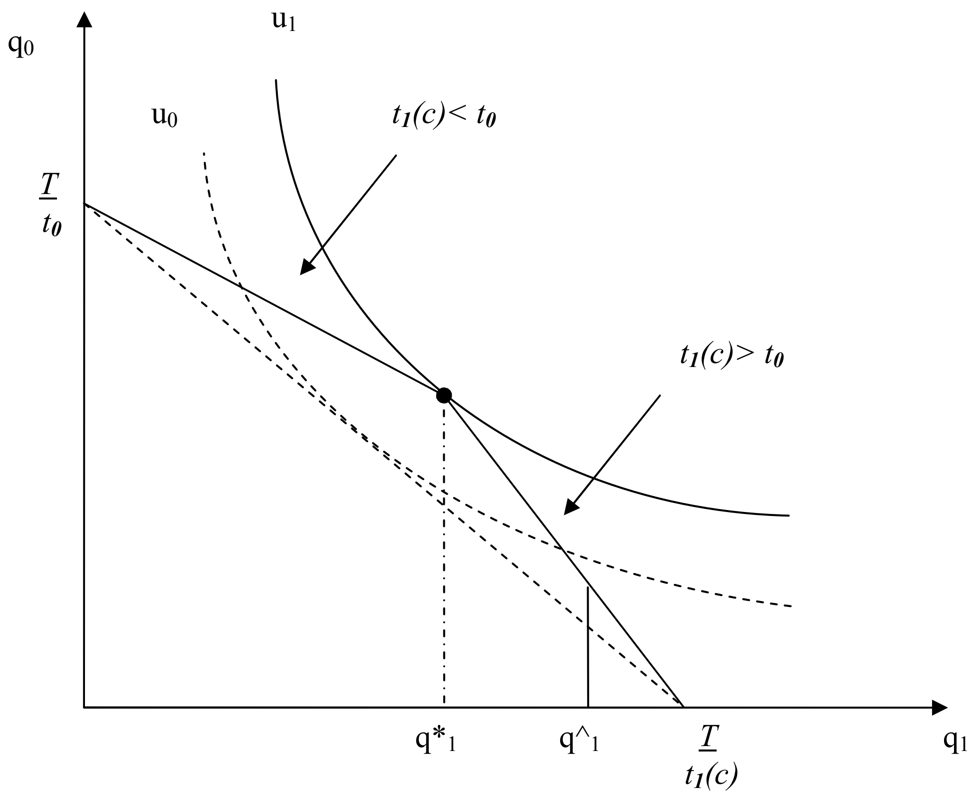
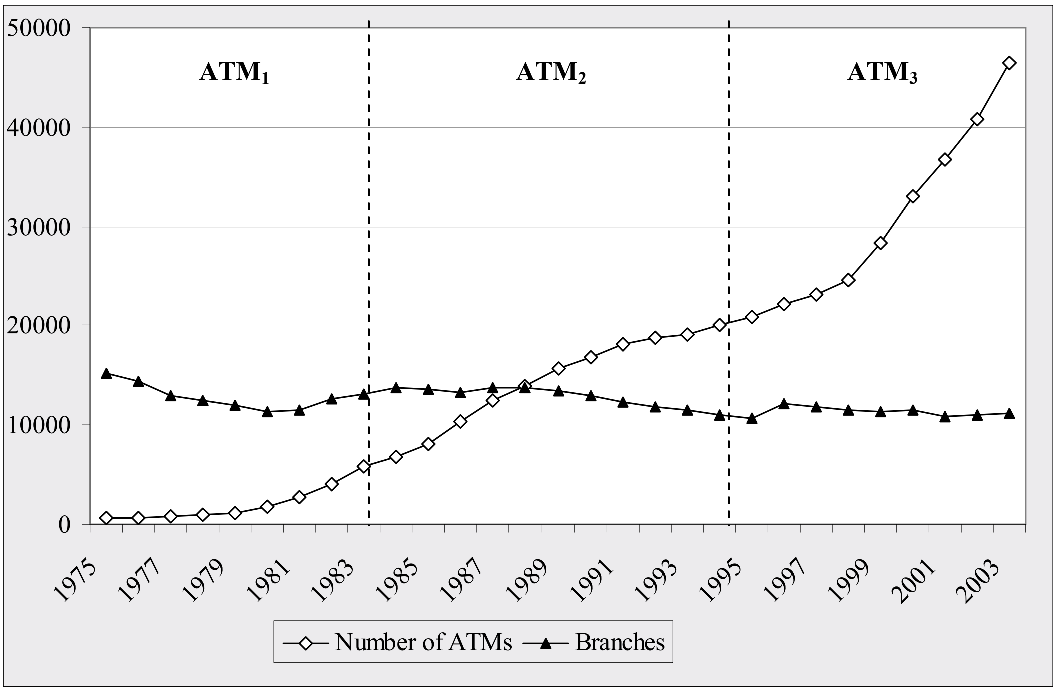


Figure 2 – Local efficiency gains out of learning

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Card Payments	3	3	4	4	5	5	6	7	8	9	10	11	12	13
Card Withdrawals	3	3	3	3	4	4	4	5	5	5	5	5	6	6
Payment Orders	5	5	5	6	6	6	7	8	8	9	8	9	10	10
Cheques	11	10	10	10	10	9	9	8	8	7	7	6	6	6
Tot. Non-Cash	**21**	**22**	**22**	**23**	**24**	**25**	**26**	**28**	**30**	**31**	**30**	**31**	**33**	**35**
Cash (Est)	79	78	78	77	76	75	74	72	70	69	70	69	67	65

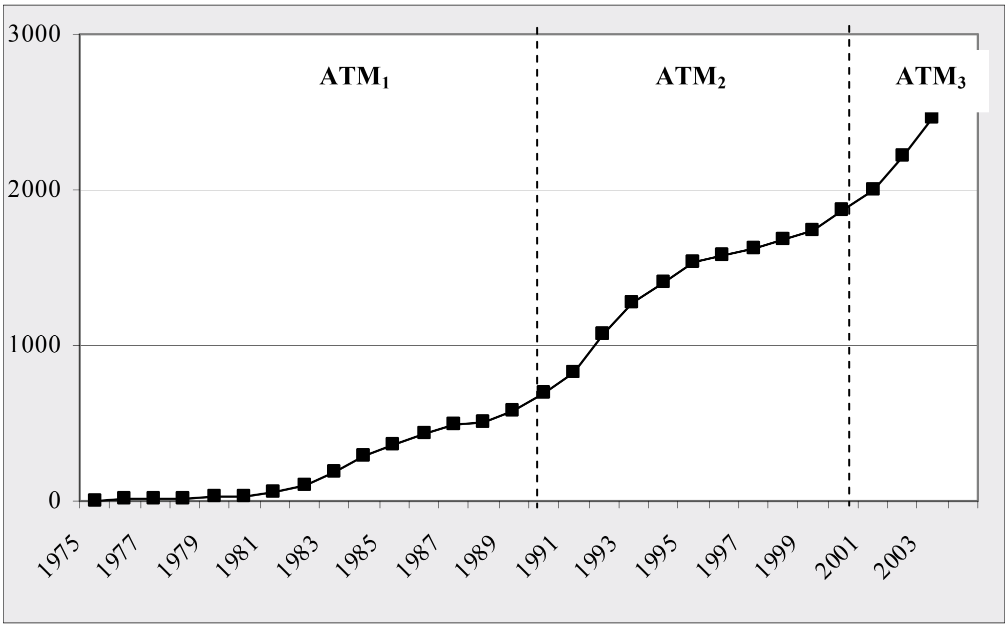
(Source: APACS)

Table 1 – Percentage value of retail transactions: UK 1990-2003



(Source: APACS, Supplementary Statistics)

Figure 3 – UK ATM network structure 1975-2003



(Source: APACS, Supplementary Statistics)

Figure 4 – UK ATM transactions 1975-2003 (Millions)