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The microeconomics of mobile payments

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Abstract

In this paper, a Kranzberg [32] - Lancaster [34] approach is employed to investigate the microeconomics of mobile payment methods. The adoption of these technical innovations depends, among others, on the acceptance by consumers that can be analyzed with a Lancaster characteristics demand. With a Kranzberg technology matrix, the technical and institutional details of payments can be transformed into salient characteristics of payment instruments that are relevant for Lancaster demand of payment methods. While cash and card-based payments are mostly Kranzberg-complete technologies, novel forms and means of mobile payments lack certain features, i.e., they are Kranzberg-incomplete innovations. Mobile payments are incomplete concerning technical, institutional and regulatory details. As a consequence, this incompleteness may result in a lack of acceptance on the side of consumers since certain salient characteristics of payment methods are not fully developed. In particular, mobile payments are neither widely accepted by merchants, nor are consumers' data and privacy protected. Kranzberg-completion of novel mobile payments is required to make them universally successful.

Keywords Payment methods and systems · Salient characteristics · Vector similarity · Kranzberg's laws · Kranzberg-complete technology packages · Network externalities

JEL classification D02 · D04 · D10 · D62 · O32 · O33

1 Introduction

1.1 Purpose of the paper

The relationship between cash payments, card-based methods and mobile payment instruments, as well as the dynamics of the competition among them, seems not so well

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understood economically [16, 17, 19]. Otherwise it would be difficult to explain why the prediction of the use of mobile payments and their actual adoption differ to such an extent (see, for instance, the Oracle White Paper by [14], pp. 9 ff., as well as the PWC Mobile Payment Report 2017 for Germany by [7]).[1]

As documented in the literature review below, in most of the papers, mobile payments are studied, mainly concerning the intention to use or the actual use of these payments by consumers. Nonetheless, there is a bunch of theoretical papers that formalize the use of different payment methods, also recorded below. They are focused on the opportunity cost of different instruments, their transaction cost, on socio-demographic aspects like income and age, as well as network externalities.

Obviously, the existing theoretical literature seems too restricted in its approach, whereas the empirical literature did not fully combine the relevant processes into a consistent and coherent model to get the whole picture right. The objective of this paper is to provide some new ideas for a theoretical analysis of mobile payments.

The conjecture in this paper is that consumers are the bottleneck of mobile payment adoption, given the current development state of mobile payment systems. Since even the similarity or dissimilarity between cash, card-based methods and mobile payments are neither sufficiently analyzed nor measured, the first addition to the literature of this paper is the suggestion of a measure for the similarity of payment systems: *the vector similarity of their salient characteristics* from a consumers' perspective. Based on this measure, the consumers' demand for the different payment instruments can be formalized, as shown below.

Furthermore, it is crucial to recognize that currently novel mobile payment methods are a technical innovation that competes with well-established, well-known and well-understood cash and card-based payment methods. Put differently, established technologies compete with a technical innovation. It is argued in this paper that novel mobile payment methods and payment systems are incomplete innovations: they lack certain technical features on the merchants' and the consumers' side, as well as institutional and regulatory features that are on a comparable level as in the case of cash and card-based systems. Therefore, currently novel mobile payment systems will be called a "Kranzberg-incomplete" technology, according to [32]; in contrast, cash and card-based payment methods and the like are in this paper assumed to be "Kranzberg-complete" technologies.[2] This is the second addition to the literature of this paper.

Moreover, all kinds of payment methods and systems are prone to (direct and indirect) network externalities. To take account of these externalities, institutional and regulatory innovations are necessary to complete the "technical innovation package" [32]. In other words, the break-through of technical innovations depends to a high degree on innovations that are not "technical" in the literal sense of the word. In this

[1] Of course, there are exceptions. For instance, in China, Japan, South Korea [41] mobile payments are widely used for certain kinds of payment. In addition, also in Kenya such payments are used, see [25]. However, because of their very different problems, in particular with infrastructure, developing countries are not considered here. – Moreover, Sweden intends to become the first country worldwide that abolishes cash as early as 2023 (Meissl Årebro [40]). A further step in the same direction is the so-called 'e-Krona' (electronic central bank money) project of the Swedish Riksbank (Sveriges Riksbank [55]). In contrast, as reported by Bech et al. [6], the demand for cash has been increasing worldwide, but its role is changing.

[2] Of course, there are countries where even cash payment methods and systems are Kranzberg-incomplete. However, the analysis of these methods and systems is not the topic of this paper.

paper, the missing institutional and regulatory supplements are discussed; this is its third contribution to the literature.

1.2 Literature review

1.2.1 Business and economic processes concerning new technologies

The available economic literature on mobile payments may be differentiated in papers whose concern is (1) the entire business and economic processes of the introduction and adoption of the new technology, (2) the competition for the technical infrastructure of mobile payments and (3) the consumers' usage decisions. Since this literature has grown rapidly and is still growing rapidly, no complete survey is intended here.[3] In Section 1.2.4, theoretical research is briefly reviewed.

In the first category (1), Au and Kauffman [2] present a comprehensive stakeholder framework for the analysis of economic questions and problems that are connected with the intrusion of disruptive technologies into economies (see Fig. 1, p. 147, in [2]). As decisive stakeholders, they identify technology producers, sellers and business intermediaries, end-users, consumers and buyers, as well as the government and regulators. Moreover, they differentiate the entire business and economic process into four phases, namely the payment technology's emergence, its diffusion and adoption and its growth ([2], p. 147). These aspects will be taken up in Section 3 of this paper.

The next paper in this category is that of Guo and Bouwman [22]. They study from merchants' views the adoption of mobile payments in China that were introduced by private companies. In addition, they review research papers that analyze the adoption of mobile payment methods from the merchants' perspective (Table 1 in [22], p. 149). Furthermore, they depict the merchants' position in the so-called m-payment ecosystem. This framework is chosen to explain the adoption of mobile payment methods since the development of the respective platforms and stimulating government policies seem not sufficient to explain the adoption process. A qualitative study underpins the complexity of the adoption process in which all tiers of the m-payment ecosystem are involved.

The third paper in this category is that of Liébana-Cabanillas and Lara-Rubio [36]. In this paper, too, the adoption of mobile payment systems is studied from a merchant's perspective. They find that neural network analysis is the tool to be applied for the prediction of the adoption of mobile payment systems.

1.2.2 Competition for the technical infrastructure of mobile payments

In category (2), the paper of Pousttchi et al. [44] could be located, as they provide an analytical framework for mobile payment business models. The framework consists of five building blocks: Infrastructure Management (assets, resources, partnerships for value creating via mobile payments), Product (bundle of consumer values of the payment provider), Consumer Interface (targeted consumers, relationship, distribution channel), Financial Perspective (cost, revenues and financing of the business model) and Threat Consideration (threats to the value of the business model; [44], Fig. 1, p.

[3] There are at least three comprehensive literature reviews on mobile payments research: [16, 17, 19].

370). Without going into details, the framework describes the ecosystem of mobile payment providers, with many interconnections, but without a viable model.

Whereas in [44] business models are structured, Ozcan and Santos [43] study how firms worldwide try to fix the architecture of the market for mobile payments. The firms or players are financial institutions, mobile operators, hardware and software providers, handset manufacturers and merchants (see Fig. 1, p. 1491 in [43]). The result of Ozcan and Santos is sobering insofar as they conclude that "the market never was": Since no agreement on the market architecture could be reached, "the" market for mobile payments is still missing. These issues are a topic in Section 4 of this paper.

1.2.3 Consumers' usage decision

Most available papers on mobile payments are in category (3). The basis of many papers is the UTAUT or UTAUT2 concept of Venkatesh et al., [57, 58]. In these two papers, the authors distilled empirically – led by theoretical conceptions – those factors that are the main drivers of IT acceptance (unified theory of acceptance and use of technology, UTAUT, [57]), as well as IT acceptance and use (UTAUT2, [58]). According to [58], Fig. 1, p. 160, the behavioral intention to use IT is driven by performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value and habit. Moderating variables are age, gender and experience. Furthermore, habit and experience play a special role as they have a more direct influence on use behavior, and not only on behavioral intention, [58].

With respect to mobile payments, a comprehensive analysis from the consumers' viewpoint is presented by Fumiko Hayashi [24]. In a qualitative early study, Mallat [39] emphasizes that the adoption of mobile payments depends on such factors as "lack of other payment methods" and "urgency" ([39], p. 413). Moreover, the identified obstacles to adoption are "… premium pricing, complexity, a lack of critical mass, and perceived risks" ([39], p. 413). In a literature review on the intention to use mobile payments, Kim, Mirusmonov and Lee [30] conclude that besides consumer-specific factors four characteristics of mobile payments are adoption-relevant: "mobility, reachability, compatibility and convenience" ([30], p. 310). This is mainly confirmed by an empirical study of Schierz, Schilke and Wirtz [50]. In an empirical study for China, Yang et al. [60] find that additionally social influences, as well as personalities, play a crucial role; moreover, the behavioral impact of the factors varies between pre-adoption and post-adoption of mobile payments. Lu et al. [38] emphasize the role of trust for the adoption of mobile payments: the trust that consumers developed with internet payment systems can influence the trust in mobile payment systems, among others.

In an empirical study with data from Portugal, Oliveira et al. [42] found that "compatibility, perceived technical security, performance expectations, innovativeness and social influence" had significant effects on adoption and recommendation of mobile payments. An investigation of in-store mobile payments in France revealed that privacy and lack of financial risk, as well as convenience, are the main drivers for this kind of payment, in combination with past experience with the method [18]. Qasim and Abu-Shanab [46] conclude from an empirical study in Jordan with teachers, master students and researchers that network externalities were the most important variable to explain mobile payment acceptance, besides performance expectancy, trust and social influence.

Arvidsson [1] summarizes the results of an empirical investigation with data from Sweden as follows: The single most important feature stimulating the use of mobile payments is ease of use. However, in addition to that, also the relative advantages of this payment method to others with respect to high trust in services (reliability) and low security risks are relevant.

In an empirical study with representative data for U.S. consumers, Schuh and Stavins [51] concluded that the use of payment methods depends on the characteristics of the payment method, by controlling for financial and demographic factors. Ease of use, security and cost determined the use of the payment method.

Recently, Schuh and Stavins [52] analyzed with U.S. data from 2013 whether "speed" and "security" do have a significant influence on the adoption of payment instruments in general. The empirical results indicate that consumers' demand for payments is not at all elastic concerning speed and security. This implies that marginal changes in both characteristics may not have an effect on payment methods. Moreover, avoiding security discontinuity may be a major factor to establish public trust in payment methods whatsoever.

Balasubramanian and Drake [4] emphasize the importance of mobile payments for developing countries. They find that service reliability is among the most important characteristics in these countries, as well as agent expertise in a competitive setting. Moreover, pricing transparency is a relevant driver of demand for mobile payments. In a field experiment in Afghanistan, where salaries by a firm were paid via "mobile money" instead of cash, the employer benefitted by significantly lower costs, whereas individual employees seem not to have similarly benefitted with respect to wealth or wellbeing [9].

To round up this review, the meta-analysis of the literature on the use of mobile payment methods of Liu, Ben and Zhang [37] is worth mentioning. They found that – in addition to the usual factors as noticed usefulness, social factors, trust and noticed risk of mobile payment instruments – "the place where consumers live" [37, p., 575] may influence the use of these methods. This might be an empirical clue that the technology adoption theories are incomplete.

Finally, the results of a study concerning a higher acceptance of mobile payments in Germany ([7], Fig. 7, p. 12) indicate the top five factors as follows:

1. "Security and data protection",
2. "Lower fees than other payment methods" and "Easy and fast use",
3. "Widespread offering and acceptance",
4. "Fewer obstacles like PINs or passwords", as well as
5. "App with attractive products or services" and "Usage by family, friends and colleagues".

Moreover, those may also be the most important characteristics that drive the use of mobile payments in other (developed) countries. At least, the results of the above empirical studies do not seem to object to this list of driving factors.

1.2.4 Theoretical research

Theoretical papers on payment instruments are extensively reviewed by Leibbrandt [35]. Cash, card-based methods, as well as electronic money instruments are included in these analyses. In addition, a number of papers exists that also include the relevance of network effects; these are, too, reviewed by Leibbrandt. Research papers on sponsored and non-sponsored standards for payment methods are included there. The results of the reviewed papers are somewhat sobering. Most of the purely theoretical papers are too far away from real-world payment methods to be able to analyze them in a usage setting. The applied papers analyze different features of payment methods concerning their network effects and the question of standardization.

Recently, Rysman and Wright [49] restricted their literature survey on the economics of payment cards. In particular, they paid attention to the literature on the effects of two-sided markets. Providers of payment instruments are in a position between merchants on the one side of the market and consumers on the other side. Therefore, interchange fees play a major role. Although this is an important aspect of payment instruments, and specially payment cards, the focus of this paper is on the technical aspects of novel mobile payment instruments and the consequences they have with respect to their adoption.

Koulayev et al. [33] attempt to explain the use of different payment instruments in the U.S. In their model (Section 4, pp. 302–304), they assume a discrete choice model where consumers choose the payment method by maximizing their expected utility. Technical aspects of the payment technology are not considered. Nevertheless, the discrete choice approach is taken up in this paper, too.

However, investigations that include the static and dynamic analysis of the adoption of Kranzberg-incomplete technologies are missing, as are studies that compare Kranzberg-complete and Kranzberg-incomplete instruments from a broad consumers' (and merchants') perspective. Shy [53, 54], Chapter 4, pp. 81 ff., may serve as an example of the prevailing theoretical approach to the adoption of technology advance. In a game-theoretic framework, the adoption of old and new, but complete technologies is modeled where consumers compete among each other. Since the technologies provide network externalities, early adoptions are risky and slow. Hence standardization is the next important theoretical topic for adoption.

Of course, network externalities and standardization are always highly relevant topics in the presence of collective effects. However, these effects – as well as their policy remedies – are well studied and well-known. The question of the adoption of Kranzberg-incomplete technologies in the presence of Kranzberg-complete ones is not yet considered.

The rest of this paper is structured as follows. In Section 2, salient payment characteristics are determined and the measurement of payment systems' (dis)similarities is defined. Using the characteristics and (dis)similarities, the demand for payment systems is formalized. The topic of Section 3 is the incompleteness of the technical innovation package. In Section 4 the missing institutional and regulatory support of mobile payments is analyzed. Section 5 concludes.

2 Payment characteristics and the demand for payment means

2.1 Outline of the theory

The microeconomic theory presented here consists of three ingredients: (1) the characteristics demand theory of [34], (2) the measurement of differences between salient characteristics by vector similarity, [13, 26, 31, 48], and (3) Kranzberg's laws of technology, [32].

Since the decision of consumers to adopt or not adopt a new payment instrument is the bottleneck of technology use, the consumers' requirements with respect to payment methods are the crucial elements of adoption. The Lancaster approach [34] allows to model this demand theoretically. Nevertheless, to define and measure quantitatively the difference between payment methods on the basis of salient payment characteristics is an important step to find out how (dis)similar they really are. The latter depends on two aspects of the payment system (consisting of the payment instrument, its usage rules and institutions, as well as its regulatory environment): (a) the use of the method by relevant others and (b) Kranzberg-(in)completeness of the payment system. For consumers, the latter two aspects are given at a certain point in time; nevertheless, they are decisive for the success and speed of adoption of the payment technology. Moreover, the use of the method in (a) will generally depend – at least to a certain extent – on the degree of Kranzberg-completeness in (b). Note that Kranzberg-completeness encompasses technical features of the payment instrument, as well as its institutional and regulatory state. A Kranzberg-incomplete method may be technically perfect; if its institutional or regulatory infrastructure is not complete, the payment method is nevertheless Kranzberg-incomplete.

These considerations document that all three elements are required for this microeconomic theory of (mobile and other) payments. This is depicted in Fig. 1.

Figure 1 shows the process of an IT innovation as, for instance, mobile payment instruments (MPI). The process begins with the technical features of the innovation that must be transformed into usage characteristics to be of value for the intended consumers. The innovation exhibits a certain degree of Kranzberg-(in)completeness that is contained in the Kranzberg technology matrix. This technology matrix encompasses all

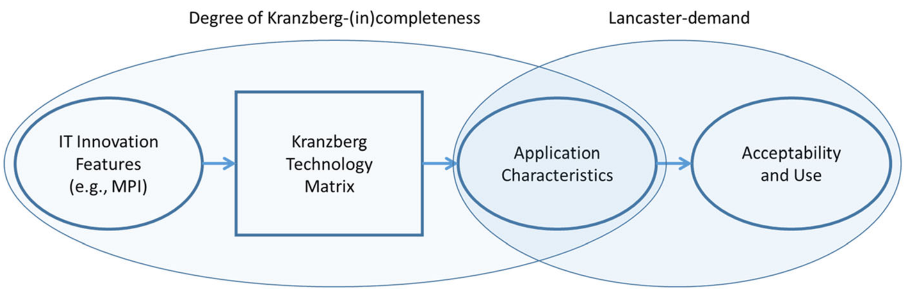

Fig. 1 Kranzberg-(in)completeness meets Lancaster-demand. Legend: MPI Mobile Payment Instrument. - Source: Own depiction

those technical, as well as institutional and regulatory, elements that transform the innovation features into usage characteristics. The final step in Fig. 1 is that these usage characteristics make the innovation (more or less) acceptable and useful, in contrast to other methods that may serve similar ends. Since the characteristics of the innovation are decisive for their use, Lancaster's characteristics demand theory is applied. It is noteworthy to emphasize that in the Lancaster approach the position of the characteristics of the different payment methods is a relative one. For instance, a payment method may be better at *Security*, but not so good at *Convenience*, in relation to another method (see [45] for further details).

2.2 Salient characteristics of payments and the (dis)similarity of payment means

First of all, to compare payment instruments (for instance, cash and mobile payments) with each other, the salient characteristics of the respective payment have to be determined (see [34] on the characteristics approach to consumer demand). As it seems, four characteristics are salient [7]: *(widespread) acceptance, security, data protection*, as well as *fast and easy use* (i.e., *convenience*).[4] Note that these characteristics are similar to those found by the former German central bank (now part of the Euro system), Deutsche Bundesbank [20], p. 32, Fig. 7, in an empirical investigation concerning the requirements for means of payment in Germany, 2017: "security against financial loss", "good overview of expenses", "easy use" and "familiarity".[5]

The *(widespread) acceptance*, a, of a payment method means whether (and at what cost) it is possible to pay outright and definitively for goods and services.[6] Moreover, it means that there is either one payment method in the respective payment instrument group (as, e.g., mobile payments) or a small number of payment methods in the same group of payments that are generally and equally accepted in a country or currency area.

Security, s, of a means of payment encompasses the risk that the payment reaches the intended receiver, but also the risk that cash or mobile payment data may be hacked, stolen or get lost accidently during the transaction.

Data protection, d, is required by consumers to ensure the privacy of transactions. The data transmitted should neither become publicly known nor used for any action that is not authorized by the consumer.

The *convenience*, c, of a payment medium is defined by its fast and easy usability. It means that no PINs, no TANs or other crypto-techniques are required. Moreover, the payment transaction must be fast such that the payment is immediately carried out.

For the following analysis, two means of payment are distinguished: cash payments, C, denominated in the national or area currency and a novel mobile payment instrument, M, that uses the currency of the respective country as the unit of account, but that is operated and run by private suppliers of the technology. To transfer payments, it is

[4] See [7] for the details of data collection. – In addition, note that the characteristics "mobility, reachability, compatibility and convenience" of [30] may be easily incorporated into the characteristics applied here. Moreover, the number of salient characteristics can be enlarged without difficulties, if necessary.

[5] Own translation of the following German notions in [20]: "Sicherheit vor finanziellem Verlust", "Guter Überblick über Ausgaben", "Einfache Nutzung"und "Vertrautheit". For details of the empirical methods of data collection and the respective values of these items see the quoted source.

[6] For a complete table of variables and their meaning see the Appendix.

assumed that mobile phones or other kinds of mobile computers as, e.g., PDAs are employed. Note that cash is a Kranzberg-complete payment instrument and also a complete payment system as its technology, as well as its institutional and legal features, and its regulation are mature and finalized. This description of novel payment instruments might seem rather fuzzy. However, to pretend that one knows all features of a payment instrument and that one is able to model exactly such an instrument would be a case in point of "the fallacy of misplaced concreteness" [59], p. 85. To compare cash payments theoretically with a novel mobile payment instrument, abstraction is required. In this respect, the "matryoshka" approach classification in [8] (and other similar classification attempts) is not very helpful as this would lead to the above-mentioned "fallacy of misplaced concreteness". However, if asked which of the levels defined in [8] is the relatively best-suited classification range for the payment instruments considered here, the answer would be "E-Money in all its forms", located in "Generic Payment Methods" in Fig. 2, p. 79.

Each payment method is formally represented by its respective *vector of salient characteristics* supposed above:

$$\overrightarrow{M} = (a_M\, s_M\, d_M\, c_M)^T, \quad \overrightarrow{C} = (a_C\, s_C\, d_C\, c_C)^T. \tag{1}$$

To measure the degree of (dis)similarity of the payment instruments, the concept of vector similarity ([13, 26, 31, 48]) is applied.

Definition 1 *Vector similarity* is defined as the cosine of the angle α between the vectors $\overrightarrow{M}$ and $\overrightarrow{C}$:

$$\cos\alpha = \frac{\overrightarrow{M} \cdot \overrightarrow{C}}{\left\|\overrightarrow{M}\right\|\left\|\overrightarrow{C}\right\|} = \frac{\sum_{i=1}^{4} M_i \cdot C_i}{\sqrt{\sum_{i=1}^{4} M_i^2}\sqrt{\sum_{i=1}^{4} C_i^2}} \tag{2}$$

where M_i (C_i) is the i-th component of the respective vector. The nominator in eq. (2) is the dot product of the vectors and the denominator is the product of the Euclidean lengths of the respective vectors.

The angle α between the vectors of salient characteristics is restricted to values between 0 and 90 degrees. An angle of zero degree (and, hence, cos $\alpha = 1$) means that the salient characteristics are completely equal, i.e., identical; hence, the payment methods are *perfect technical substitutes* for each other. An angle of 90 degrees (and, hence, cos $\alpha = 0$) between the vectors implies that the means of payment are *perfect technical complements* to each other, since their salient characteristics are completely dissimilar.

Definition 2 A payment method M *technically dominates* a method C if and only if each of the four components of the vector $\overrightarrow{M}$ is at least as large as the respective component of the vector $\overrightarrow{C}$ and if additionally at least one component of $\overrightarrow{M}$ is strictly larger than that component of $\overrightarrow{C}$ (et vice versa):

$$\overrightarrow{M} \gg \overrightarrow{C} \Leftrightarrow M_i \geq C_i, \quad \forall i, i = \{a, s, d, c\} \text{ and } M_{a(s,d,c)} > C_{a(s,d,c)}. \tag{3}$$

Definition 3 A payment method M is *technically preferable* to a method C if and only if the length of the vector $\overrightarrow{M}$ is larger than the Euclidean length of vector $\overrightarrow{C}$ (et vice versa):

$$\overrightarrow{M} > \overrightarrow{C} \Leftrightarrow \sqrt{\sum_{i=1}^{4} M_i^2} > \sqrt{\sum_{i=1}^{4} C_i^2}. \tag{4}$$

Definitions 1 to 3 can be employed to characterize the technical relation between different payment methods. Next, the demand for the means of payment M and C will be determined. The decisive link between the salient characteristics of payment instruments considered here and the demand for such methods is a technology matrix (the Kranzberg matrix), as defined below.

2.3 The demand for payment instruments

As pointed out in Prinz [45], money demand can be decomposed into the demand for salient money characteristics. This approach is also applicable to payment methods. Let $U\left(\overrightarrow{G}(1+n), z\right)$ be a concave utility function over a vector of salient payment characteristics $\overrightarrow{G} = (a\ s\ d\ c)^T$, as defined above, and n the number of the respective payment method users. The inclusion of the number of users represents a network externality (see for a general analysis [27] and for electronic money [56]). The more people use a particular payment system, the higher the utility of this system and its characteristics. Note, however, that each consumer uses one and only one payment method. Furthermore, let Y be the income of a consumer and z a monetary variable that does not contain payments for goods or services. Moreover, define q_i, $i = M, C$, as the variable that indicates to which method the monetary value of the goods and services, P, are paid for. The technical constraint for the transformation of characteristics into payments is given by (for this and the following formalization see [47], p. 79):

$$\overrightarrow{G} = B \cdot q, \tag{5}$$

with $B = b_{ij}$ as the technology matrix that transforms the vector of payment methods, q_i, $i = M, C$, into the characteristics vector, $\overrightarrow{G} = (a\ s\ d\ c)^T$. Note that some elements of the matrix may be zero. Furthermore, the elements b_{ij} are not restricted to values of zero and unity. They represent the respective payment method's degree of suitability concerning the salient characteristics.

Equation (5) can also be written as follows:

$$B \cdot q = \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \\ b_{31} & b_{32} \\ b_{41} & b_{42} \end{pmatrix} \cdot \begin{pmatrix} q_M \\ q_C \end{pmatrix} = \begin{pmatrix} b_{11}q_M + b_{12}q_C \\ b_{21}q_M + b_{22}q_C \\ b_{31}q_M + b_{32}q_C \\ b_{41}q_M + b_{42}q_C \end{pmatrix} =: \begin{pmatrix} a \\ s \\ d \\ c \end{pmatrix} = \overrightarrow{G}.$$

The choice variables are the payment instruments, cash and mobile payments, whereas the technology matrix B determines how the payment methods are transformed into the characteristics vector, $\overrightarrow{G}$. The technology matrix is decisive for whether and to which extent the payment methods deliver the desired characteristics. Put differently, the technology matrix contains the features of the respective payment *system* that are relevant for the characteristics of the respective payment method. Hence, the technology matrix may also be called the *Kranzberg matrix of the payment system*, as related to the characteristics of the payment method. Note that institutional and regulatory determining factors are integral parts of a payment system and, therefore, of the technology or Kranzberg matrix.

For consumers who decide on the use of a method of payment, the Kranzberg matrix is given. However, one or some of the coefficients of the Kranzberg matrix could be zero (or a small number). In this respect, the Kranzberg matrix may indicate the technological incompleteness of the respective *payment system*.

The budget constraint of a consumer is given by:

$$Pq_M + Pq_C = Y - z, \tag{6}$$

where the price of z is assumed to be equal to unity. Equation (6) may be interpreted as follows. On the left-hand side, the total expenditures for consumption goods and services are represented, that are paid for exclusively either by cash (indicated by subscript C) or a mobile payment method (indicated by subscript M). If the payments are made in cash, $q_C = 1$, $q_M = 0$, and if they are carried out as mobile payments, $q_C = 0$, $q_M = 1$. The parameter P denotes the monetary value of the payment for goods and services.

On the right-hand side of eq. (6), Y is the consumer's income and z can be interpreted as the consumer's savings.

The general consumer optimization program is to maximize $U\left(\overrightarrow{G}(1+n), z\right)$ subject to the constraints (5) and (6).

An interesting approach is presented by [47] (p. 80); it is applicable in cases where consumers have to select one payment method only (for a more general formalization of binary choice models via indirect utility functions see [23]). In this case, the choice can be simplified by exploring the conditional utility of the respective currency:

$$q_i^* = \underset{q_i}{\operatorname{argmax}}\, U\left(\overrightarrow{G}(1+n_i)|q_i\right) \tag{7}$$

with respect to the restrictions given by eqs. (5) and (6). This is a discrete choice problem that requires the calculation of the utility levels that are attainable by the respective payment method characteristics; the method with the highest utility level is chosen then.

In the context of two means of payments that can be *combined in different ways*, i.e., $q_i \in [0, 1]$, $i = C, M$, and $q_M + q_C = 1$, this solution seems not to be adequate. Applying the direct utility approach of Kim et al. [29] (see also [15], pp. 985 ff.), the specified utility function can be written as:

$$U(P \cdot q, z) = \textstyle\sum_i B_i \cdot (P \cdot q_i)^\beta \cdot (1 + n_i) + z^\gamma, i = M, C. \tag{8}$$

In addition to the already defined variables, $0<\beta<1$ is the preference parameter for the goods and services and $0<\gamma<1$ the preference parameter for savings.

The Lagrangian for maximizing (8) subject to the budget constraint (6) is given by:

$$\mathcal{L}(q_M, q_C, z, \lambda) = B_M \cdot (Pq_M)^{\beta} \cdot (1+n_M) + B_C \cdot (Pq_C)^{\beta} \cdot (1+n_C) + z^{\gamma} + \lambda(Y - Pq_M - Pq_C - z), \tag{9}$$

with $B_M = \sum_{j=1}^{4} b_{Mj} = \sum_{j=1}^{4} b_{1j}$ and $B_C = \sum_{i=1}^{4} b_{iC} = \sum_{i=1}^{4} b_{i2}$ from eq. (5).

The first-order conditions for a maximum of eq. (9) are:

$$\beta P B_M (Pq_M)^{\beta-1}(1+n_M) - \lambda P = 0, \tag{10}$$

$$\beta P B_C (Pq_C)^{\beta-1}(1+n_C) - \lambda P = 0, \tag{11}$$

$$\gamma z^{\gamma-1} - \lambda = 0, \tag{12}$$

$$Y - Pq_M - Pq_C - z = 0. \tag{13}$$

According to eq. (13):

$$\lambda = \gamma z^{\gamma-1}. \tag{14}$$

Inserting (14) into (10) and (11), respectively, and solving the equations for the respective payment method demand, results in:

$$q_M = \left(\frac{\beta P B_M (1+n_M)}{\gamma z^{\gamma-1}}\right)^{\frac{1}{1-\beta}}, \tag{15}$$

$$q_C = \left(\frac{\beta P B_C (1+n_C)}{\gamma z^{\gamma-1}}\right)^{\frac{1}{1-\beta}}. \tag{16}$$

A comparison of the eqs. (15) and (16) reveals that the demand of both methods depends negatively on the optimal level of savings, z. Moreover, they also depend positively on the preference parameter β and the respective characteristics indices, B_M and B_C, as well as on the respective number of payment method users, n_M and n_C. Since *both* payment methods may now be used by a consumer, $n_M + n_C \geq N_T$, with N_T as the total number of consumers in the economy.

However, up to this point it has not been considered that the methods may be technically more or less similar, as defined by the cosine of their salient characteristics vector, $\overrightarrow{G}$. Since by definition $q_M + q_C = 1$, it follows:

$$q_M = 1 - \cos\alpha, \;\; q_C = 1 - q_M = \cos\alpha. \tag{17}$$

Therefore:

$$\cos\alpha = 1 - \left(\frac{\beta P B_M (1 + n_M)}{\gamma z^{\gamma - 1}}\right)^{\frac{1}{1-\beta}} = \left(\frac{\beta P B_C (1 + n_C)}{\gamma z^{\gamma - 1}}\right)^{\frac{1}{1-\beta}}. \tag{18}$$

Equation (18) shows that the elements of the Kranzberg matrix, B_M and B_C, and, hence, the (dis)similarity of the payment methods, are decisive for the demand of payment methods. Note that the respective number of users in eq. (18) is the perceived or expected number of users in this model.

3 Kranzberg-incompleteness of the mobile payment technical innovation package

In this section, the Kranzberg-incompleteness of the mobile payment innovation package will be demonstrated. Note that the Kranzberg matrix connects payment methods characteristics with the Lancaster demand for payment instruments. Moreover, the characterizations used in this section refer to payment systems, whereas the salient characteristics in Section 2 refer to payment methods.

In Fig. 2, the embeddedness of the mobile payment instruments (MPI) is depicted. In this diagram, the environment of MPI consists of the providers of mobile payment services, SP, the merchants, Ms, that will collect their consumers' payments, and the consumers, Cs, who pay for their products (see also [2], pp. 146 ff. and Fig. 1, p. 147). Finally, public policy, PP, is involved in all aspects of the transactions between SP, Ms and Cs. Note that lines with two arrowheads in Fig. 2 reflect mutual, bi-directional connections of the relevant participants in a payment network, whereas lines with one arrowhead show the impact of public policy on the payment network participants. Note that PP may

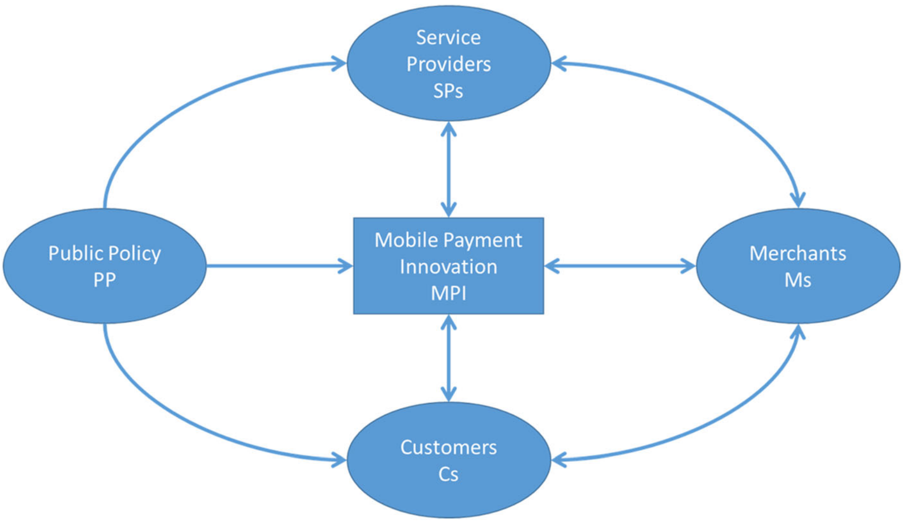

Fig. 2 Mobile payment innovations and their embeddedness. Source: Own depiction

also influence the merchants, Ms, which is for the sake of simplicity not explicitly depicted in Fig. 2.

According to Kranzberg's second and third 'law' of technological development, "[i]nvention is the mother of necessity" as it requires "… additional technical advances in order to make it fully effective" ([32], p. 548) so that "[t]echnology comes in packages, big and small" ([32], p. 549). Applying these 'laws' to the technical innovation of mobile payment systems, one can delineate for each of the players in Fig. 2 the necessity for further innovations.

(1) *Service providers* compete with each other since no dominant system exists and the future development and regulation of mobile payment systems is not yet finished. Moreover, the already existent systems are neither completely compatible nor connected with each other.
(2) *Merchants* are still innovating their payment instruments. Since several methods are used by consumers side by side as, for instance, cash, debit and credit cards, innovations like mobile payments require merchants' investments and additional costs. Insofar, it is unclear to which extent merchants "must take" or "wanna take" payment innovations, [10]. With French shopping data, Bounie, Francois and van Hove [11] conclude that concerning card payments, consumer acceptance was the driving force to merchants' adoption. As no dominant mobile payment instrument is in sight, the implementation of MPIs is risky and incomplete.
(3) *Consumers* are innovating their shopping behavior that may put additional pressure to the commercial systems of merchants. Although the use of mobile methods to compare products and prices within shops is very common, mobile payments are not. The reason is that the most wanted usage characteristics, as mentioned in the introduction, are not always and not everywhere met by the available MPIs. Put briefly, additional technical, as well as institutional and regulatory innovations are necessary to make MPIs widely acceptable and useable.
(4) *Public policy* faces strong pressure to innovate the legal standards to make mobile payment systems safer and to adapt the rules of consumer protection. Furthermore, clear liability rules are required, in particular for situations in which hackers and other disruptions hit the mobile payment system. Additionally, changes of tax rules might be required. Finally, mobile payments may also require innovations in the public governance system itself (e-governance, for instance).
(5) *Interactions* of consumers and merchants may demonstrate that further innovations are necessary to take consumers' behavioral innovations and adaptations into account. A changing payment behavior of consumers (e.g., by using 'family and friends'-payment methods) may make further innovations in the payment system necessary.
(6) Finally, public policy may prescribe legally *standards* and features of mobile payment systems. That may render some of the existing systems dominant players in the market. This might change the competition between payment service providers in a very profound way, with further consequences for adaptations and innovations.

The crucial point is that the 'innovation necessities' sketched above are extremely relevant for the characteristics of mobile payment instruments; these characteristics determine the consumers' choice of payment methods. This impact may be dubbed "indirect network externality", as suggested by Basu, Mazumdar and Raj, [5].

(1) *Acceptance* depends on the number of mobile payment systems: the more systems compete with each other, the lower the acceptance of the whole mobile payment system. Missing standardizations of mobile payment methods do also decrease its acceptance. Last but not least, the higher the (mostly non-pecuniary) user cost of mobile payments the lower their effective use.
(2) *Security* is a serious feature in all monetary transactions. Hacking of digital methods is a well-known issue, as is cyber security in general. Virus and ransom attacks are wide-spread phenomena, in addition to identity theft. As it seems, the security scripts for financial transactions require innovations to a larger extent to meet the security level of cash transactions. The legal and regulatory framework is also in dire need of innovations to foster security.
(3) *Data protection (privacy)* is one of the key dominant features of cash payments. Although there are good reasons to consider anonymity of payments as dubious, there are probably even better reasons to guarantee privacy of data concerning payments. Otherwise the data may be used to exploit consumers' wishes and willingness to pay in such ways that large parts or even the entire consumer surplus is captured by suppliers. Individual and social freedom seems not feasible when there is total control of financial transactions. However, it may be only a matter of time until the regulatory framework for payments enforces complete transparency, maybe by rendering cash payments illegal. This will not solve the here mentioned data protection and privacy issue.
(4) *Convenience* is another feature of payment methods that consumers prefer. In this respect, mobile payments have the potential to be much more convenient than cash and card payments. The point is, nonetheless, that mobile payments are not standardized. At least, different mobile payment instruments by the various suppliers should be compatible with each other.

To sum up, at the time being mobile payments lack a large number of additional technical, institutional and regulatory innovations until a complete technical mobile payment package is available. Put differently, MPIs are Kranzberg-incomplete. Although the inertia of consumer behavior and the habituation of cash payments are obstacles to the diffusion of mobile payments, the Kranzberg-incompleteness of the technical payment innovations seems to be at least as serious an obstacle as consumers' payment habits.

4 Institutional and regulatory support for mobile payments

In the previous sections, network externalities of payment systems are mentioned; see [35] for a comprehensive discussion. However, a closer look maybe necessary to see the institutional and regulatory obstacles for mobile payment systems.

As it seems, public policy is lagging some way behind in determining the legal and regulatory framework for technical innovations, particularly in IT. For a widespread acceptance of IT-based payment innovations as mobile payments, nation-wide compatible or even unified systems are required. Put differently, the installed base is decisive. The reason is that otherwise direct and indirect network effects cause obstacles to the adoption of the new technology. Moreover, with respect to the institutional and regulatory framework of payment systems, the existing structures are not sufficiently adapted for a smooth implementation of mobile means of payment. The disruption due to innovations of payment methods may be scaled up by gaps in the institutional and regulatory framework.

The latter issues are crucial because of the just mentioned network effects of payment methods. The existing institutional and regulatory gaps give reasons for a rather large number of different mobile payment systems that exist side-by-side. Liability rules are not well-defined, security protection seems to be in its infancy and financial institutions operate with very different technical and institutional arrangements.

Among other reasons, this lack of a supporting institutional and regulatory infrastructure restricts the number of mobile payment adopters. Uncertainty about the future usability of mobile payment methods, r, is a major obstacle for their further development. The expected number of mobile payment users, $E\left[n_M^{t+1}\right]$, is determined by the relative price, e, of the mobile payment method to cash,[7] its salient characteristics vector, $\overrightarrow{G}$, and its usability r:

$$E\left[n_M^{t+1}\right] = h\left[e_{M,C}^{t+1}\left(n_M^t\right), \overrightarrow{G}^{t+1}\left(n_M^t\right), r^{t+1}\left(n_M^t\right)\right]. \tag{19}$$

According to eq. (19), all variables determining the expected number of mobile payment method users on the right-hand side of eq. (19) depend on the past number of those users. This corresponds to the direct network effect of payment methods, as formalized in the demand for payment methods in Section 2.3 above.[8] As documented by the UTAUT and UTAUT2 models in [57, 58], expectations about the technology's performance, but also social influences and habits play a role for the intention and the actual use of a new technology. Acceptance is the higher, the larger the perceived acceptance and willingness to use.

[7] Note that the relative price of mobile payments and cash payments consists mainly in the non-monetary costs of the (in)convenience of use. While cash, for instance, is ubiquitously accepted, mobile payment is not.

[8] As demonstrated by Dybvig and Spatt [21], in a static environment the government may induce agents to adopt a new technology – payment method –, by supplying a kind of insurance scheme for the case that not enough agents adopt the new technology. However, the government must know at least the preference distribution of agents concerning the technologies.

To sketch in a very general form the dynamics of payment method adoption, suppose that the expected future number of mobile payment users, $E\left[n_M^{t+1}\right]$, as well as the average payment per user, $\overline{P \cdot q_M^t}$, is determined by adaptive expectations or "error learning" (see for the following formalization [3], pp. 25 f.):

$$E\left[n_M^{t+1} \cdot \overline{P \cdot q_M^{t+1}}\right] = \lambda \cdot n_M^t \cdot \overline{P \cdot q_M^t} + (1-\lambda)E\left[n_M^t \cdot \overline{P \cdot q_M^t})\right], \tag{20}$$

with $\lambda \in [0, 1]$ as the error correction multiplier. For $\lambda = 0$, the expected usage of mobile payments at time t, $E\left[n_M^t \cdot \overline{P \cdot q_M^t}\right]$, is extrapolated without any correction for the deviation from the actual number at time t. For $\lambda = 1$, the realized usage of mobile payments at time t is extrapolated into the future while ignoring the expected number for time t. However, the crucial effect is the network externality (n_M) included in $E\left[n_M^{t+1} \cdot \overline{P \cdot q_M^{t+1}}\right]$.

The inspection of these equations shows that the prospective numbers of mobile payment users are co-determined by the currently effective number of mobile payment users or the installed base of it. The more similar the salient characteristics of the payment systems, the less likely it will be that the new mobile means of payment will gain value and usage (see [28] for a general analysis and [56] for e-money). In contrast, the more dissimilar the payment methods are, the larger the number of its users will become, and the higher the transaction volume it will gain.

The crucial question is, however, which are the most important institutional and regulatory features to supplement and support mobile payment systems? Widespread acceptance of mobile payments requires the features shown in Fig. 3.

The core layer in Fig. 3 concerns the mobile payment method (MPD) itself. To make cash payments contestable, mobile payment methods require technical standardization.

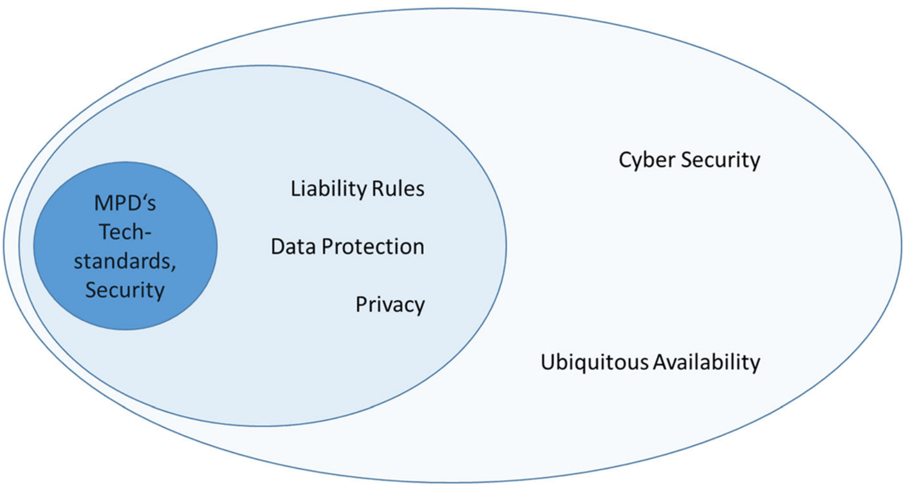

Fig. 3 Layers of supporting institutional and regulatory features. Source: Own depiction

The latter is also important for merchants. If the payment technology is not standardized, it is difficult to decide which technology to apply. Moreover, using different, non-compatible mobile payment methods side by side may be expensive. Whether the standardization is implemented by the industry itself or legally prescribed, does not matter so much in this respect.

The second layer is mainly a regulatory one. First of all, liability rules must be clearly defined and adapted to the mobile payment technology. Liability rules are expected to influence the technical development of MPDs, since certain technical components might be required to comply with liability rules. From an economic point of view, it is worthwhile to emphasize that liability rules determine who bears which risks. Hence, liability or risk-bearing rules must be incentive-compatible, as well as cost-efficient. This could be a hard-to-solve issue for legislators and method engineers.

Additionally, privacy of payments must also be guaranteed since otherwise the privacy of cash might remain its comparative advantage. The blockchain technology, for instance, could solve security issues of MPDs and guarantee privacy [12].

The third layer is a very general one. Institutional, as well as regulatory innovations seem to be necessary to increase cyber security. Malware, the hacking of systems and many other forms of cyber risks and attacks require a much better cyber infrastructure. Since mobile payment systems are embedded in the cyber world, the further development and success of mobile payments puts pressure on infrastructure development.

Additionally, mobile payment methods must be ubiquitously available at low cost. This is predominantly an issue for an adequate payment infrastructure. The convenience of payments could be the leading topic to guide infrastructural innovations.

All in all, these aspects stress the importance of Kranzberg's "Fourth Law": "Although technology might be a prime element in many public issues, nontechnical factors take precedence in technology-policy decisions" ([32], p. 550). Policy decisions are very often path-dependent, i.e., there are not many policy revolutions. Existing institutions, as for instance liability rules, are very resistant to change, even if there are better solutions. Technology revolutions, therefore, take time to come into full effect. Furthermore, special interest groups might also play an important role in the adoption of technologies ([32], p. 552).

Nevertheless, without innovations of the infrastructure and the "rules of the payment game", the current network advantage of cash may continue. Put differently, the completion of the mobile payment innovation package requires institutional, infrastructural and regulatory innovations along the lines sketched here.

5 Conclusion

In this paper, the microeconomics of payment systems is based on three basic concepts: (1) a Lancaster approach concerning the characteristics of payment instruments as perceived by consumers, (2) the Kranzberg theory of technology innovation packages, as well as (3) direct and indirect network externalities.

(1) In particular, the Lancaster approach is extended by making the characteristics' distance between payment methods measurable with vector similarity. To understand (and to measure) the similarity and dissimilarity of payment methods, four salient characteristics of payments are considered: acceptance, security, data protection and convenience. Given the specificity of the salient characteristics of cash, their (dis)similarity can be measured by vector similarity. With this concept, the substitutability or complementarity of payment systems and the competition among them can be analyzed. Payment methods will be technical complements if they are dissimilar and they will be substitutes if they are very similar. Competition is expected to be the fiercer the more similar the respective payment methods are. Moreover, a payment instrument may become dominant if it provides advantages regarding *all* salient characteristics.

(2) The Kranzberg theory of technology innovation packages is applied to mobile payments to analyze whether the package of this innovation is complete. With the Kranzberg theory, the individual microeconomic perspective of payment methods is complemented by the technical, institutional and regulatory payment environment. Put differently, Kranzberg's technology "laws" transform a payment method into a payment system. By combining the incompleteness of the technology innovation package "mobile payment methods", called "Kranzberg-(in)completeness", with the salient characteristics of payment methods, it becomes understandable why the consumers' adoption of mobile payment methods did until now not fulfill the expectations.

(3) As all other payment methods, mobile payments are also prone to direct and indirect network externalities. With the combination of the extended Lancaster-approach and the Kranzberg-theory the additionally required technical, institutional and regulatory innovations can be determined to complete the mobile payment innovation package. Within a Kranzberg-complete mobile payment system, indirect and direct network effects may support rather than impede the usage of these payment systems by consumers. The reason is that standards, clear liability rules, data protection and privacy, in combination with convenience, can make it easier and securer for consumers, as well as cheaper for merchants, to use mobile payment methods.

To put it briefly, the result of the microeconomics of mobile payment systems suggests that without the completion of the mobile payment technology innovation package, its usage may probably not be as effective and efficient as it could be in the digital age.

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Compliance with ethical standards

Conflict of interest The author declares that he has no conflict of interest.

Appendix

Table 1 Table of variables

Salient characteristics of payment methods	
a	Acceptance
d	Data protection
c	Convenience (fast and easy use)
s	Security
$\overrightarrow{G}$	Vector of salient characteristics
$\overrightarrow{C}$	Vector of salient characteristics: cash
$\overrightarrow{M}$	Vector of salient characteristics: mobile payments
Payments	
C	Cash
M	Mobile payment (by smartphone or PDA)
Demand for payment instruments	
$U(\ldots)$	Concave utility function
n	Number of payment method users
n_C	Number of cash users
n_M	Number of mobile payment users
$B = b_{ij}$; i: salient characteristics; j: C, M	Kranzberg technology matrix
$B_M = \sum_{j=1}^{4} b_{1j}; 1 = M$	Sum of salient characteristics of mobile payment method
$B_C = \sum_{i=1}^{4} b_{i2}; 2 = C$	Sum of salient characteristics of cash
Y	Income
P	Consumption expenditures
z	Savings
q_C	Share of consumption expenditures paid by cash
q_M	Share of consumption expenditures paid by mobile payments
β, $0 < \beta < 1$	Preference parameter consumption
γ, $0 < \gamma < 1$	Preference parameter savings
t, $t + 1$	Time
$E[\ldots]$	Expected value operator
r	Future usability of mobile payment methods
$e_{M,C}$	Relative price of cash and mobile payments
$n_M^t \cdot \overline{P \cdot q_M^t}$	Average absolute payments of mobile payment device users at time t
$n_M^{t+1} \cdot \overline{P \cdot q_M^{t+1}}$	Average absolute payments of mobile payment device users at time $t + 1$
$\lambda \in [0, 1]$	Error correction multiplier

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