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A General Equilibrium Approach of Retail Payments

(A pénzforgalom modellezése általános egyensúlyi keretben)

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Abstract

In our paper, we introduce the Hungarian Payment System Model (HUPS), a computable general equilibrium model with detailed payment services which can be used for policy evaluation and forecast. In the last years, several studies investigated different aspects of payment systems and some papers used equilibrium theory to study a specific segment or question of retail payments. In our paper, we take a step forward as we extend this research using the general equilibrium approach. The HUPS model is a large and highly disaggregated computable general equilibrium model with 25 economic agents and nearly 100 payment services, which cover most of the payment system supply chain in Hungary. It contains 7 types of costs for each payment service, varying degree of economies of scale, oligopoly and cross-product pricing and agent behaviour adjustments to payment method costs. In our model, the payment sector is an integrated part of the economy as every actor has to make payment decisions related to its activities. As a result, the model can be used for thorough economic evaluation of many kinds of policies and other changes in the field of retail payments. The HUPS model is calibrated on the large and up-to-date information base of Hungarian payment statistics, surveys and studies – most notably the Hungarian cost of payments study – which makes it a powerful and robust modelling and forecasting tool.

JEL: C68, E27, E42
Keywords: payment economics, CGE modelling, retail payments, cost of payments

Összefoglaló

Tanulmányunkban bemutatjuk a magyar pénzforgalmi rendszer elemzésére készített HUPS – *Hungarian Payment System* – modellt. A HUPS egy számszerűsített általános egyensúlyi modell, amely részletesen kidolgozott pénzforgalmi szolgáltatásokat tartalmaz, és a fizetési rendszert érintő közpolitikai döntések hatásainak kiértékelésére és előrejelzésre is alkalmas. Az elmúlt években több tanulmány is született a pénzforgalmi rendszerek különböző közgazdasági kérdéseiről, és egyes tanulmányok egyensúlyelméleti módszereket is használtak e kérdések megválaszolásához. Tanulmányunk újdonsága, hogy a pénzforgalmi rendszer leírását egy zárt általános egyensúlyelméleti keretbe foglaljuk. A HUPS modell egy nagyméretű, dezaggregált, számszerűsített általános egyensúlyelméleti modell 25 különböző gazdasági szereplővel és közel 100 különálló pénzforgalmi szolgáltatással, amelyek lefedik a magyarországi pénzforgalmi ellátási lánc jelentős részét. A modellben 7 költségtípust különböztetünk meg, eltérő mértékű mérethozadékokat, valamint oligopolista- és keresztárazást is alkalmazunk. A modellünkben a pénzforgalmi rendszer a gazdaság mélyen integrált része, ahol minden szereplőnek pénzforgalmi döntéseket kell hoznia a tevékenységéhez kapcsolódóan. Ennek eredményeként a modellünk alkalmas a pénzforgalmat érintő gazdaságpolitikai döntések kiértékelésére, valamint a pénzforgalmi szokásokban bekövetkező változások hatásának előrejelzésére. A HUPS modell kalibráláshoz felhasználtuk a magyarországi pénzforgalmi statisztikák, felmérések és elemzések sokrétű, részletes és aktuális adatait – különös tekintettel a fizetési módok társadalmi költségét felmérő tanulmányra –, ami biztosítja, hogy a modell segítségével megbízható és robosztus elemzések és előrejelzések készíthetők.

Contents

1. Introduction

Since the birth of the first currencies, the execution of payments became one of the most important economic activities. Nearly every economic act, be it trade or redistribution of the created values needs to use the payment system. For a long time, cash was the one and only means of payment execution. Later, other forms of payment methods appeared such as cheques or in recent decades electronic payments such as credit transfers, direct debits and card payments. The execution of payments is one of the most important and crucial economic acts and has been studied from several aspects. From the perspective of money theory, Nosal and Rochateau (2011) give a comprehensive investigation, but only a few studies have been published in the academic field to understand the microstructure and the production of this unique service. For lack of a solid theoretical foundation from academic fields, no applied models exist to this point which can incorporate the payment systems in a general economic framework. Because of the dynamic changes in the payment methods and habits, and because payment systems are deeply integrated into the entire financial system and economy the need for such models is greater than ever. It is also important that we be able to assess all of the economic consequences of payment system policy decisions and changes in regulation of retail payments. In our paper, we introduce the Hungarian Payment System Model (HUPS), a computable general equilibrium model with detailed payment services which can be used for policy evaluation and forecast.

In the last years, several studies investigated different aspects of payment systems. The four most notable segments are the drivers of payment behaviours and payment method choice, the connection between the retail payments and the real economy, the economics of payments and the cost of payments. Some papers used equilibrium theory to study a specific segment or question of retail payments, e.g. the choice of payment instruments or the impact of a change in regulation.

Over the course of the last decade, there were several empirical studies analysing the drivers of the payment methods choice of the consumers, for example Bolt and Chakravorti (2008) and Kalckreuth et al. (2009). These empirical studies are pivotal in modelling payment behaviour. Klee (2008) uses grocery store data for empirical analysis, Polasik and Fiszeder (2008) study online shopping habits.

Hasan et al. (2009) studies the impact of a more advanced payment system on the profitability of the banking sector using panel data for EU members. Following this methodology in their paper, De Renzis, Hasan et al. (2013) analyse the connection between the retail payment systems and the real economy for the members of the European Union. They use panel data to show that a more sophisticated electronic payment infrastructure – for example the use of credit and debit cards for payments – correlates with higher GDP per capita. They calculate that a 1.2% increase in card penetration would increase GDP by 0.07% and SEPA implementation alone would result in 0.02% GDP growth. Moody's Analytics (2013) conducted a similar study demonstrating the connection between the development of a financial infrastructure and the real economy.

Chiu and Lai (2007) give a comprehensive review of the payment economics literature, most notably the Freeman (1996) model and the Kahn and Roberds (2006) model, their extensions and the simulators used for the LVTS, the Canadian RTGS to study system risks. These models primarily model the most basic notions of payments and settlements, the motivation of the agents and the characteristics of the different systems – limited enforceability, double wants, float, etc. This theoretical approach does not fall in line with our focus of building an applicable policy evaluation tool, as in our model we use very different models and estimations for the utility of payments and focus primarily on their costs and productions.

The European Central Bank carried out a study (Schmiedel et al. (2012)) of the social and private costs of different payment instruments with the participation of 13 national central banks in the European System of

Central Banks. This study shows that the costs to society of providing retail payment services are substantial, on average; they amount to almost 1% of GDP for the sample of participating EU countries. The authors grouped the countries into five categories and proved that for most countries there is still room for the development of a more effective payment system. One of the participants in this study was the Magyar Nemzeti Bank (MNB, the central bank of Hungary) with its own cost of payments study (COP, Turján et al. (2011)) which provides a detailed and comprehensive analysis of the Hungarian payment services supply chain, the costs of the different agents and several activities involved in the execution of payments. The study encompasses a vast number of datasets received from the different payment services providers in Hungary and surveys completed by the MNB. The COP study provides the basis of our model with many aspects of the underlining technologies and pricing routines.

Alongside the COP study, the MNB actively studies different aspects of the retail and large value payment systems of Hungary. Based on a 1,000 and a 300-sample study, Takács (2011) gives a detailed account of the payment behaviours of the Hungarian household sector. Using another 1,000-sample survey, Ilyés and Varga (2015) update and expand the results. These studies show the unique aspects of the Hungarian payment system from the side of the consumers. Helmeczi and Olasz (2011) studied the motives behind the below average use of direct debits in Hungary, and Helmeczi (2010) maps retail transactions in Hungary on geographical data.

Divéki and Olasz (2012) studied the pricing of payment services in Hungary and proved that a high degree of cross-pricing is persistent in the payment system. Ilyés et al. (2014) also provide some evidence on the pricing behaviour of Hungarian payment service providers. Turján (2009) analysed the postal payment services in Hungary and several studies of Bódi-Schubert et al. (2012,2014) studied the role of cash in the economy and in the lives of enterprises. Before the implementation of the interchange limiting regulation of 2013, Keszy-Harmath et al. (2011) studied the role of interchange in card schemes in general and in the case of Hungary.

In our study, we take a step forward to extend this research and create an applied model of the retail payment infrastructure which can be used for policy evaluations. Since the payment system is fully integrated into the entire economy and is influenced by and affects every other part of it our main goal is to create a computable general equilibrium model which focuses mainly on the issues of the retail payments.

The HUPS model builds on the long history of computable general equilibrium models in Hungary. From the HUMUS system (Zalai (1984)) to the HUGE model of the Ministry of Finance (Révész et al. (1999) several large CGE models were built to study impacts of changes in regulation, for example the GEM-E3 model (Révész et al. (2014)). The HUPS model incorporates the payment system into a similar theoretical framework.

Besides the CGE models there are several other macroeconomic models for policy evaluation in Hungary, the DYNAMO model of the Ministry for National Economy (Dózsa et al. (2014)), the ECO-LINE and the SOCIO-LINE model (Cserháti et al. (1998, 2001, 2002)). The MNB created the Hungarian Quarterly Projection (NEM) model and the Monetary Policy Model (MPM) for the analysis of monetary policy decisions. Since the HUPS model is a static CGE model, it does not follow the structure or the basic assumptions of these models.

Our paper is structured into five parts. In Chapter 2 we describe the basic structure of the model including the captured payment services and the idea of how we incorporate them into the model. Chapter 3 contains the model equations. Due to the size of the model, we do not list every equation but the main forces that govern the agents in the model. In Chapter 4 we describe the main information bases of the model, the methods of calibration and solution of the model. In Chapter 5 we demonstrate the model by evaluating two scenario analyses in the calibrated model. In the first scenario, we evaluate the impacts of the forecasted improvement in payment habits based on the current trends. The second scenario calculates the needed intervention to reach the tipping point of cash and card acceptance costs for retail transactions. Finally, we elaborate on the possible future extensions of our model and conclude.

2. Model structure

In this chapter, we outline the basic structures of the model, the relevant agents of the payment services supply chain and describe the payment services in the model. Since the payment services and the financial infrastructures in Hungary have some unique attributes, we first briefly describe the Hungarian payment systems to better understand the choices made during the creation and calibration of the model. After that we explain the agents of the payment services industry and the huge number of payment services embedded in the model. In this chapter, we do not explain the technical details of the model, as the equations and behavioural characteristics are described in the next chapter.

2.1. RETAIL PAYMENT SYSTEM AND SOME UNIQUE ATTRIBUTES IN HUNGARY

The retail payments infrastructure of Hungary predominantly shows the same characteristics as in other economies, but with some unique aspects. For consumers and enterprises, payment services are provided mostly by credit institutions and other specialised actors such as payment institutions or e-money institutions. The biggest and most important payment service providers are commercial banks. In Hungary, no domestic card scheme exists but two large and some smaller international card schemes are present in the country. The Hungarian Automated Clearing House (GIRO Zrt.) operates the interbank clearing system for retail payment transactions such as credit transfers and direct debits. The RTGS system of Hungary is called VIBER which is widely used for interbank payments, high value business payments included.

Basically, retail payments in Hungary is still a strongly cash dominated segment with about 80-90% of all transactions – in volume – paid in cash. Despite this high figure, the financial infrastructure in Hungary is well developed with more than 82.7% of households maintaining a payment account and 80% possessing a debit or credit card. Both statistics show that account coverage is high in Hungary and nearly all household have access to the financial infrastructure. The reason behind the high number of cash transactions is mainly cultural and historical; Hungary has only two decades of development in modern payment transactions, but the growth rate of the more developed, electronic system is above the European average.

Card payments have exhibited a double-digit increase in volume and value in the last years and now nearly 13% of all household purchases in value are made by credit or debit card (Table 1). This figure is still less than half of the European Union average, but the gap is closing at a fast rate. The payment cards issued in Hungary use the most advanced systems, practically all cards are equipped with EMV chips and close to 40% of them already have contactless capability. Credit transfers initiated by households use an increasingly modern and effective structure with intraday clearing and settlement and the share of paper-based orders dropped from 20% to 7% in the last decade.

Table 1
Changes in the indicators measuring the level of development of the Hungarian payment services compared to the EU

Index	Definition	Hungary 2013	Hungary 2014	European Union 2013
Credit transfers	Annal value of credit transfers/GDP	15,8	16,1	17,2
Electronic payment of retail purchases	Annual value of payments made by payment cards or other electronic solutions/ Annual household consumption	12,8%	14,9%	27,9%
Electronic payment of utility bills and other service charges	Estimated annual value of direct debits and other electronic bill payments / Estimated annual value of bill payments	24,3%	25,4%	70%*

** Estimated value-based on the data supply of individual EU Member States, per capita core direct debit figures and the study of Deutsche Bank (2005). From MNB (2014).*

The use of other advanced electronic payment methods shows a mixed picture. The increase in the share of direct debits stopped in the 2010s and the volume and value of transactions has stabilised since. The reason behind this trend is the popularity of the postal inpayment money order (PIMO), a service offered by the postal system of Hungary. The PIMO – commonly referred to as the "yellow cheque" in Hungary although it has no connection to cheques in the usual sense – is an order usually filled in advance by the payee with the necessary information which can be paid by cash in all post offices around Hungary. This option is very popular for utility and other recurring payments with about 75% of these payments still made through the postal system. The use of PIMOs is on the decline, but their overwhelming share puts the use of direct debits in Hungary well under the European average. Traditional cheques are practically non-existent in Hungary.

Corporates on the one hand still operate with a relatively high usage of cash, e.g. cash acceptance is still prioritised to card acceptance by many small and medium-sized merchants because of the lower direct costs. On the other hand, government regulations have sharply reduced the use of cash in B2B transactions. In those cases the use of credit transfers is popular, which results in a relatively high credit transfer per GDP ratio for Hungary, at 16.7, compared to the European average.

The payment habits of customers and the payment systems and regulations in Hungary are changing dynamically which means a complex and changing landscape. Older elements of the system are still operating while the newest innovations in the world e.g. contactless payments and mobile payments are already appearing on a large scale in Hungary. We built our model to be able to cope with this vibrant and dynamically changing sector and to be flexible enough to be adjusted to a wide range of payment system supply chains.

2.2. BASIC MODEL STRUCTURE

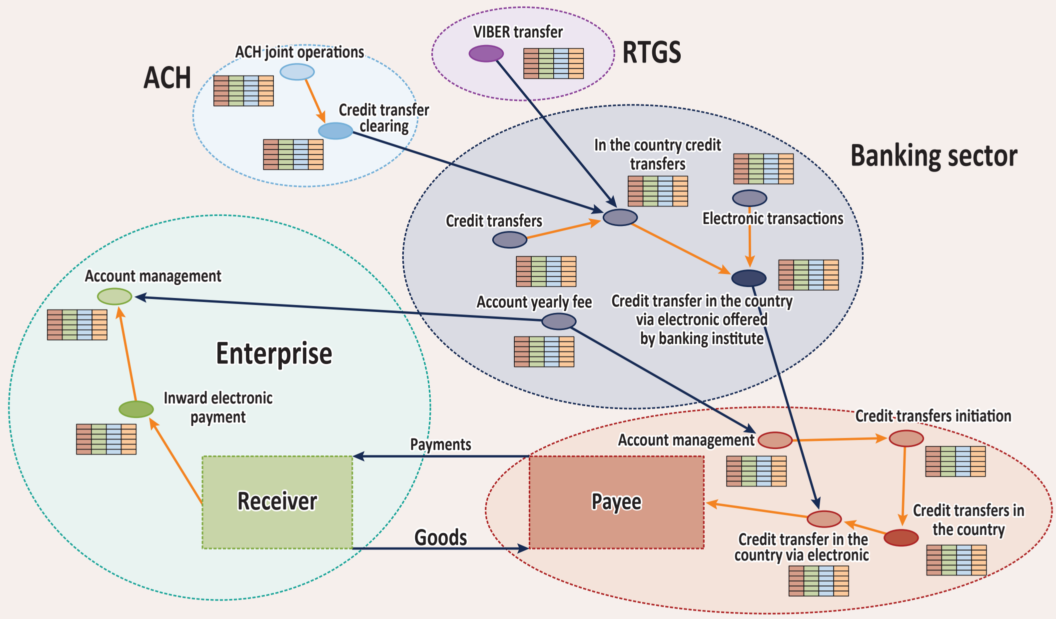
The HUPS model is a static computable general equilibrium model for a small open economy with different kinds of non-competitive behaviour such as cross pricing and monopolistic mark-up profit. The main focus of the model is to answer policy questions related to pricing, cost shocks, taxation and shadow cost of goods and services. Our choice was to build a static model to meet this demand. With a static model we can greatly increase the model to several thousands of variables and still be able to solve for a wide range of parameterisation. A dynamic model would be harder to calculate for a high number of markets and is unlikely to be calibrated precisely given that most of the information source of the model is cross sample and not time series data. Since the payment services supply chain is a complex, highly disaggregated part of the economy it was crucial to us to be able to increase the size of the model without concerns to solvability.

The model consists of a few aggregate sectors of enterprises, differentiated actors of the payment services supply chain, an aggregate sector of households, a governmental agent and the rest of the world (ROW). By building the static HUPS model we do not insert capital accumulation and intertemporal decisions into the model, which are mostly unrelated to payment system operation, but we have an extremely detailed payment system supply chain with 10 different payment service provider agents, 160 activities and 15 branches of the economy. Given the size of the model it cannot be solved by conventional methods, but even with the extremely increased number of relations and variables policy changes can be evaluated by the HUPS's unique solution mechanism.

2.3. ECONOMICS OF PAYMENTS

Despite being a macroeconomic model, the HUPS model has strong micro foundations. The microeconomic theory of payment management and payment execution has not yet been integrated into the mainstream theory. In our model and in the underlying theory, the payment execution is a market service with a market price produced by a specialised economic agent (payment service provider, PSP) but it also entails internal costs on both the recipient's and payer's sides. The internal payment execution cost of the different economic actors can be a mix of the used labour, the capital cost of the employed infrastructure and imports or intermediate consumption. Each of these costs is further broken down to seven types with varying degree of economies of scale, thus leading to 28 cost elements for every activity. We give a detailed description of the production function and the cost structure in Chapter 3. The fifth cost element of payment execution consists of the market price of payment services bought from the PSPs and the shadow costs of other not direct activities necessary to the execution of payments.

Chart 1
Production costs and relationships for credit transfer via electronic payments



**The nodes represent activities (light colour) and market services (dark colour), the lines represent production relations (red = inner production, black = market transactions), the tables represent the 4 times 7 different type of costs.*

For example, in the case of domestic product purchases paid by the electronic channel credit transfer, both the customer and the enterprise have their own internal costs and used payment services (Chart 1). To execute this payment the household requires the final activity of executing 'domestic interbank credit transfer via electronic channel'. This activity in our theoretical framework is an inner service produced and consumed by the household. Its 4 times 7 cost elements are all the costs which can be only allocated to this kind of payment method. As an input the household also uses a secondary intermediary activity, 'credit transfers domestic interbank' which contains all the costs that can be allocated to domestic interbank credit transfers – via electronic, paper and telephone. The root activity of credit transfers contains the activities that are present in every credit transfer. Another secondary activity is account management which is also needed to execute payments via credit transfer. All of these activities are inner services, but the household also uses market services to produce them. The leaf activity uses the banking service 'credit transfer domestic interbank via electronic' which has a market price and also account management requires paying yearly fees to the banking institute.

To put the theoretical model into perspective based on the calibration data of the HUPS model (Chapter 4), for an average value domestic electronic credit transfer, the shadow cost of the household agent is 248 HUF per transactions (Table 2). Only 54 HUF is value-based cost, the rest is volume-based. Of the total 248 HUF, 207 HUF is the fee payed for market service 'domestic electronic credit transfer' of the banking agent. The rest is inner shadow cost – time cost of the transaction – and the share of account fees associated with credit transfers. For the banking agent the cost associated with all types of credit transfers is 100 HUF, the cost of electronic payments is 54 HUF, and the rest is the profit margin. From these we can calculate the total shadow costs of the agent.

Table 2
Cost structure of electronic credit transfers for households and banking agents

Households		Banking agent
248 HUF total cost		**207 HUF market price**
54 HUF value-based	207 HUF fees paid	100 HUF credit transfer cost
194 HUF volume-based	41 HUF inner costs	54 HUF electronic transaction cost
		53 HUF profit margin and cross pricing

In this example the enterprise side is simpler; it only needs to accept payments, which requires the presence of an account. For the banking institute to produce this activity, we broke down the activities in the same way as for the household inner services. Every cost is allocated to the deepest level where it applies. This results in a three level tree with a unique side activity only for electronic based transaction processing. The complexity of the PSPs is recognisable also in this case as the banking institute uses services from the ACH for clearing and from the RTGS for settlement leading to complex supply chain even for a simple credit transfer payment.

Each of the listed activity is doubled to volume and value. This is a unique characteristic of the payment system since the pricing routinely depends on values also – as a percent of the transferred money for example. This two-level structure of the same execution and settlement of a payment is connected by average transaction values and jointly dependent costs detailed in Chapter 3 of our paper.

The model uses 82 different payment activities with both value and volume which leads to a total 164 new services in the model. The 82 payment activities can be grouped as shown in Table 3.

Table 3
Categories of activities and services in the payment services supply chain

	Intermediate activity	Final activity
Payment methods	e.g. time spent on credit transfer executions	e.g. credit transfer domestic interbank via paper
Payment services offered to end users	e.g. internal bank costs of paper-based transactions	e.g. credit transfer domestic interbank via paper service offered by credit institutions
Payment services inside the supply chain	e.g. joint internal cost for ACH operations	e.g. ACH clearing

Another significant change from the usual form of general equilibrium models is the use of a price system that is not homogenous of degree zero. Most of the prices of the payment services are in percent of the transaction value. Also, the output level of the production is based on the price system, since the production of the desired value of execution is in nominal value and cannot be transformed to real value. Despite this, it can be proven that equilibrium exists under general assumptions. The equilibrium is not unique in the usual way, a part of the economy is homogenous of degree zero to the price system, another part is of degree one. Bearing that in mind, a different uniqueness definition can be created and most of the usual results of the mainstream theory can be applied.

The two major groups of agents – producers and consumers – have different internal structure of decisions. Both the corporate sector and the payment service providers have a profit maximisation problem which is greatly extended with the management and costs of payment services. Households have a utility maximisation problem, while other types of end consumers like the central and local government and ROW have some kind of rule of consumption.

2.4. ENTERPRISES

The corporate sector has a basic profit maximisation problem defined with a CES-Leontief production function and the need of executing payments – inward and outward transactions. The sector pays wages for the labour used in production as well as an expected return on fixed capital stock. A level of substitution exists between labour and capital, but not between intermediate consumption and imports.

To find the optimal ratio of capital and labour used in production the enterprise solves its profit maximisation problem and takes into account the full costs of the resources used. For this, it produces payment services for itself – inner costs of payment executions – and buys payment services from the market, from the payment service providers. After calculating the total costs of payments execution, the shadow prices of the resources used are updated and used for calculation of the optimal ratio.

The problem of the enterprise is extremely complex, due to the level of recursiveness in its production, meaning that in order to produce inner payment services to execute payments – for example paying wages – it uses the same resources whose shadow price depends on the cost of executing the related payments. This problem shows how complex an exercise it is to fully integrate the payment services into a classical microeconomic approach.

Using different levels of aggregation changes the number of agents in the sector – different branches of the economy – and the number of intermediary inputs and accordingly the size of the model. In our model we distinguish between the following sectors of enterprises:

1. Agriculture
2. Mining
3. Manufacture
4. Heavy industries
5. Machinery production
6. Construction
7. Trade
8. Transport
9. Postal activities
10. Public administration
11. Telecommunication
12. Financial services
13. Other market services
14. Public services
15. Others

The distinction of the above categories of branches was made mostly with the purpose of creating groups within the economy with presumably homogeneous payment habits. The secondary aspect of the chosen aggregation was to separate industries that are relevant to the payment system supply chain – for example postal services, transport, telecommunication.

2.5. PAYMENT SERVICE PROVIDERS (PSPS)

The core of the model is the highly disaggregated payment services supply chain. The HUPS model employs seven unique agents of the supply chain. Some of these agents represent unique companies, or a group of companies, or an autonomic division of an agent.

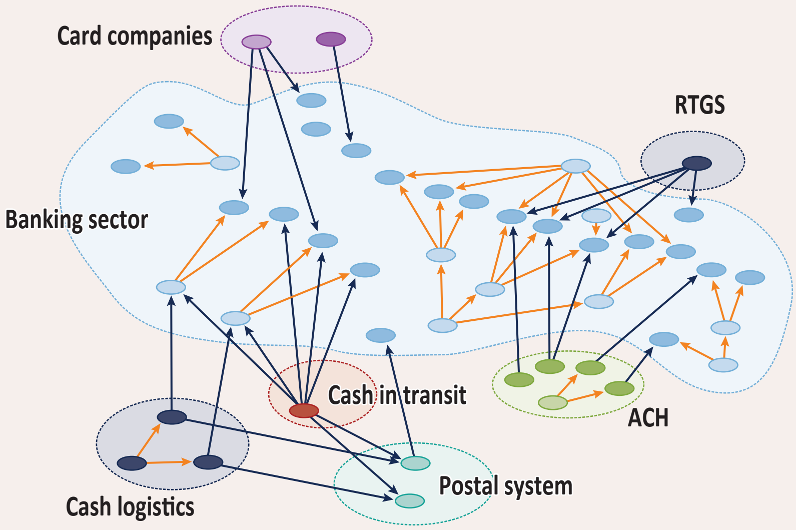
2.5.1. Types of PSPs

The payment supply chain agents of the model are the following:

1. Credit institutions
2. Postal system
3. Card companies
4. Cash in transit companies
5. Automated clearing house (ACH)
6. Real Time Gross Settlement System (RTGS)
7. Cash logistics function of the central bank (CL)

The seven PSPs in the model are connected through a web of different services and activities (Chart 2). Most of the market services (dark dots) and activities (light dots) belong to the banking institutes. The credit transfer and direct debit side of their activities requires the use of services from the RTGS and the ACH. The other half of their portfolio is mainly payment card related operations. The cash withdrawal and cash deposit supply chain requires the CIT for logistics, the CL for bill and coin production and in cases of inter-bank services the card schemes for clearing. The remaining services are activities which do not need a detailed disaggregation, for example account management, card issuing and postal system related services.

Chart 2
The inner service structure of the payment services supply chain
(activities, inner production, and intermediate consumptions)



**The nodes represent activities (light colour) and market services (dark colour), the lines represent production relations (red = inner production, black = market transactions)*

2.5.1.1. Credit institutions

The biggest agent in the supply chain is the representative agent of the different credit institutions – including the cooperative credit institutions – offering a wide range of the payment services detailed in the model. These services include credit transfers, cash deposits and withdrawals, direct debits, credit and debit card purchases and account management. The agent only represents the retail payments divisions of these institutions; the rest of these firms belong to the corporate sector in our model.

2.5.1.2. Postal system

The postal system in Hungary consists of one public company which is an important agent in the payment services supply chain offering two actively used services, the postal inpayment money order for households and the public payments in cash. The postal inpayment money order – referred to as "yellow cheque" in Hungary but has nothing to do with the common meaning of the term "cheque" – is a popular way of executing regular payments, for example utility bills. Based on statistical data collected by the MNB, nearly 75% of utility bills are currently paid by "yellow cheques". Public payments in cash mostly consist of pension payments, and a smaller part is social payments. The post in Hungary – the Magyar Posta Zrt. – also owns a cash-in-transit company, but it is detailed separately at the relevant agent.

2.5.1.3. Card companies

Since Hungary has no national card scheme, the relevant two large and some smaller international firms are not detailed, card production and card purchases clearing are listed as import of services. The sector is included in the model for policy purposes since these costs affect directly the cost of other activities for the banking agent.

2.5.1.4. Cash in transit companies

The representative agent of the three CiT companies in Hungary is offering logistics services to the banking agent, the post and for the corporate sector.

2.5.1.5. Automated clearing House (ACH)

The Hungarian automated clearing house (GIRO Zrt.) operates the interbank clearing system for retail payments. Since the ACH also offers business services not related directly to clearing of payments, the rest of the company is separated and only the clearing services, and its costs and technology are used. The ACH is owned by the central bank of Hungary and it follows a strictly cost-based pricing method.

2.5.1.6. Real Time Gross Settlement System (RTGS)

The MNB (the central bank of Hungary) has two distinct functions portrayed in the model. The VIBER is the RTGS system of Hungary which is widely used for interbank payments, but it is also used for high value business payments and for this reason it is included in the model. The price of VIBER transactions is cost-based – the MNB operates the system on a non-profit basis – therefore the separate inclusion into the model is well-founded.

2.5.1.7. Cash logistics function of the central bank

In its cash logistics (CL) function, the MNB is responsible for the production of coins and bills in the country. Similarly to the RTGS, the MNB's cash logistics operation is non-profit and is priced mainly cost-based. Both the RTGS and the CL have their own cost allocation centres for the calculation of the prices the MNB sets for customers which means that the separation of these two divisions can easily be done.

2.5.2. Types of payment services

The model uses 82 different types of payment activities, of which 20 are market services with existing market prices. The remaining activities are intermediate production performed inside the company and by the final consumers and have shadow or transfer prices. Every one of these activities is doubled – because the volume and value of transactions make up separate markets as discussed in Section 2.2. This means that the full extent of the model with resource markets and the different branches of the economy reaches up to 200 different goods and services detailed.

We give a comprehensive list of all activities and services inside the payment services supply chain, grouped in the same way as was shown in Section 2.2. End-user payment methods are means of executing payments and intra-agent activities that are needed to produce them.

End-user payment methods

1. Cash payments
    1. cash payments outward
    2. cash payments inward
2. Credit transfer
    1. Credit transfer outward
        i. Credit transfer intra bank
            1. Credit transfer intra bank via paper
            2. Credit transfer intra bank electronic
            3. Credit transfer intra bank initiated in batch
        ii. Credit transfer domestic interbank
            1. Credit transfer domestic interbank via paper
            2. Credit transfer domestic interbank electronic
            3. Credit transfer domestic interbank initiated in batch
        iii. Cross-border credit transfer
            1. Cross-border credit transfer via paper
            2. Cross-border credit transfer electronic
        iv. RTGS credit transfer
    2. Credit transfer inward
3. Direct debit
    1. Direct debit intra bank outward
    2. Direct debit domestic interbank outward
    3. Direct debit inward
4. Postal payments
    1. Postal inpayment money order outward
    2. Postal inpayment money order inward
    3. Public cash payments outward
    4. Public cash payments inward
5. Card payments
    1. Card purchases outward
        i. Card purchases intra bank outward
        ii. Card purchases domestic interbank outward
    2. Card purchases inward
6. Not explained transactions
    1. Not explained cash inward
    2. Not explained cash outward
    3. Not explained electronic inward
    4. Not explained electronic outward

End-user payment services are market services offered by the payment service providers to corporate and private customers. The final services have market prices; the intermediate activities only have shadow prices. The payment services pricing is one of the most crucial aspects of the model with detailed behavioural methods. We will describe the modelled pricing processes in detail in Chapter 3.

End-user payment services

7. Banking payment services
    1. Cash withdrawal
        i. Cash withdrawal for households
        ii. Cash withdrawal for corporations
    2. Cash deposit
        i. Cash deposit for households
        ii. Cash deposit for corporations
    3. Card merchant fee
    4. Cards
        i. Card issuing
        ii. Yearly card fee
    5. Account yearly fee
    6. Bank credit transfer outward
        i. Bank credit transfer intra bank
            1. Bank credit transfer intra bank via paper
            2. Bank credit transfer intra bank electronic
            3. Bank credit transfer intra bank initiated in batch
        ii. Bank credit transfer domestic interbank
            1. Bank credit transfer domestic interbank via paper
            2. Bank credit transfer domestic interbank electronic
            3. Bank credit transfer domestic interbank initiated in batch
        iii. Bank cross-border credit transfer
            1. Bank cross-border credit transfer via paper
            2. Bank cross-border credit transfer electronic
        iv. Bank RTGS credit transfer
    7. Bank direct debit
        i. Bank direct debit intra bank outward
        ii. Bank direct debit domestic interbank outward
        iii. Bank direct debit inward
    8. Bank card purchases outward
        i. Bank card purchases intra bank outward
        ii. Bank card purchases domestic interbank outward
    9. Postal services
        i. Public cash payment initiation
        ii. Postal inpayment money order completion

Despite the fact that the model uses only 6 different payment methods, the number of marketed payment services is well above 60. This classification means that within the model we use the following simplifications:

- Postal cash withdrawal is in the same variable as any other kind of cash withdrawal.
- The cross-border transactions are highly aggregated. Detailing them by different payment methods would not significantly improve the model based on their small volume.
- Regular transactions are in the same variable as normal credit transfers.
- Cash deposit is not detailed by the channel, it is entirely unnecessary.
- From the multiple postal services we only use the two with overwhelming share of volumes, the public cash payment initiation – pensions and social transfers – and postal inpayment money order, a payment method widely used in Hungary for invoice payments.

Some payment methods are detailed only in limited extent. For example, the household does not know if a card purchase is intra bank or not, also the CIT companies do not differentiate by corporate and banking customers.

Most payment methods and the related services can be connected to one agent in the model which produces them and set the price. The banking sector provides most of the market services; the remaining agents provide only a few. The only exception is the not explained transaction type which has no producer and cost structure. The intermediate payment services belong to the inner side of the payment services supply chain, and include activities not used directly by end-users of the infrastructure.

Intermediate payment services

8. ACH
    i. ACH credit transfer
    ii. ACH credit transfer initiated in batch
    iii. ACH direct debit
  1. ACH direct debit reception
  2. ACH direct debit completion
9. CIT
    i. Cash in transit transport
11. Central bank
    i. RTGS
  1. RTGS transfer
    ii. CL
      1. Cash production
        a. Cash selling
        b. Cash purchase
12. Card companies
    i. Card system clearing
    ii. Card production
13. Credit institutions
        a. Paper-based order
        b. Electronic order

As we can see, inserting the payment system supply chain into a general equilibrium model greatly increases the size of the model.

2.6. HOUSEHOLDS

The households offer capital and labour in the market, their income consists of their share in profits, salaries and government transfers. The households spend their income on consumption of goods and services, the execution of payments and savings. Similarly to the social cost of payments studies, the capital, labour and consumption good costs of the execution of payments are taken into account as well. This means that the households produce the inner services of payments execution and are effectively partly a producer. This approach is in sharp contrast to the neoclassical separation of the producers and consumers, but can be applied in the modelling framework by the creation of a shadow branch of the economy which produces these inner services to the households. Naturally, these services are not market services. Because the aim of the model is the evaluation of policies concerning the payment systems, we use the simple approach that the supply of the primary resources of the economy – capital, labour – are not affected by retail payment policies and thus remains constant. Because of the size of the payment systems – around 1% of GDP – we believe that this simplification can be easily accepted. With the use of regular resource supply functions, the solution of the model becomes considerably harder with no significant effect on the results.

2.7. GOVERNMENT

The governmental agent collects taxes, pays transfers to the other agents and spends the remaining income on either savings or public consumption. The tax and transfer arm of the model is strictly SNA (system of national accounts) based. Because of the focus of the model, taxation is an important part of the different policy scenarios and thus evaluation.

Similarly to the household sector, the governmental agent also executes payments – both inwards and outwards – which are represented by a unique shadow branch in the economy.

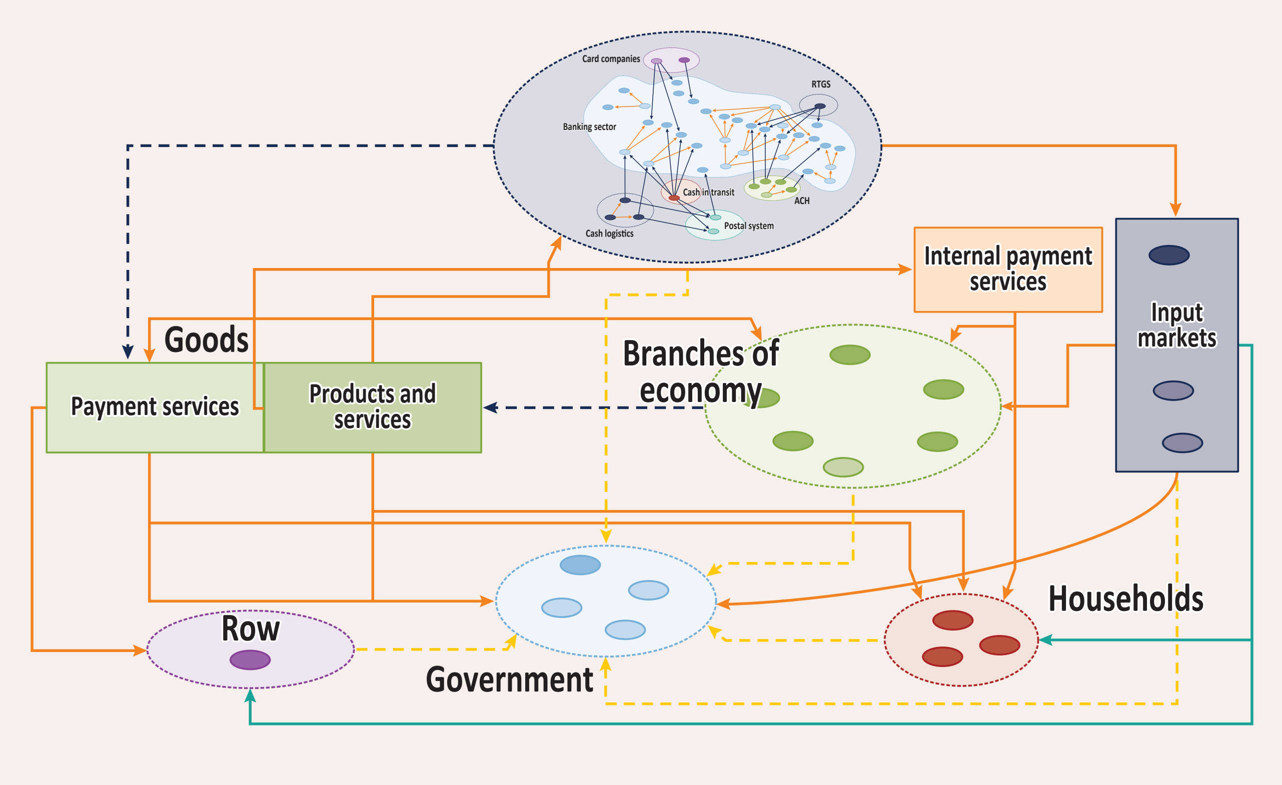
2.8. REST OF THE WORLD AND OTHER SECTORS

The last agent is the representative agent of the household auxiliary sector and the rest of the world sector in the national accounts. These agents rarely affect the payment system and are portrayed in our model in a very simplified manner.

3. Model equations

In this section, we present the typical equations of the model. Because of the detailed production functions and 25 agents and highly integrated payment decisions, the HUPS model has nearly 12,000 primary variables and ten times more secondary variables. The model's size does not allow us to present each equation used in our calculations, so we restrict ourselves to the most important ones.

Chart 3
The basic structure of the model
(black-supply, red-demand, yellow-taxation, green-income)



The model's basic structure follows the structure of general CGE models (Chart 3). The agents can be grouped as households, government, real production sector and the ROW. The households and ROW offer capital, labour and imports in the input markets, and receive incomes, wages and profits from the enterprises. The government collects taxes and buys goods on the products and services markets. The deviation from the mainstream models is the complete separation of the payment system supply chain from the other branches of the economy and the inner processes of the other agents. The goods market is divided to payment services, other services and products markets. The internal payment services – activities – are separated from the corporate and household agents.

For most of the standard variables of the model we use the mainstream names, we denote Y to output, X to intermediate consumption, C to final consumption, L, K and M to labour, fixed capital and import and p to prices. We use i to differentiate between agents, m as an index to payment services and j to branches of the economy. The capital letters of these indices indicate the number of agents and services. In the Appendix we give the complete denotation list of parameters and variables used in the HUPS model.

3.1. THE PROBLEM OF ENTERPRISES

The corporate sector produces 15 types of composite goods, uses labour, capital, intermediate consumption and imports as inputs. The enterprise pays different types of taxes, pays for the used payment services and uses its own resources to execute payments. The profit function is the following formula. φ_m is the per volume-based fee of the relevant payment service, φ_m^v is the nominal value-based fee. We use PS_{mi}^D and PS_{mi}^{Dv} for the volume and value of the demand for payment services. *NTX* is the net sum of taxes paid by the agent.

$$\pi_i^p = p_i \cdot Y_i - w \cdot L_i^D - r \cdot K_i^D - \sum_j^I p_j \cdot X_i^j - p_m \cdot M_i - \sum_m^M \phi_m \cdot PS_{mi}^D - \sum_m^M \phi_m^v \cdot PS_{mi}^{Dv} - NTX_i \quad \text{3.1-1. Equation}$$

The equation states that the profit of the agent is the difference between its revenue and the costs of inputs. The cost part is expanded by the costs of payment services used.

The corporate agent maximises profit bounded by the cost structure determined by the technological set:

Net taxes:

$$VAT\left(p_i \cdot Y_i - \sum_j^I p_j \cdot X_i^j - p_m \cdot M_i\right) + r \cdot K_i^D \cdot TXK + TXL \cdot w \cdot L_i^D + OTX_i + TXY \cdot p_i \cdot Y_i = NTX_i \quad \text{3.1-2. Equation}$$

Primary good production:

$$Y_i = \min\left(\left(AL_i^y \cdot L_i^{Dyv^{-\sigma_i}} + AK_i^y \cdot K_i^{Dyv^{-\sigma_i}}\right)^{-\frac{1}{\sigma_i}}, \cdots, A_x^i \cdot X_i^y, \cdots A_m \cdot M^y\right) \quad \text{3.1-3. Equation}$$

Payment services:

$$f_Y^{im} \cdot p_i \cdot Y_i + \sum_j^J f_{xj}^{im} \cdot p_j \cdot X_i^j + f_L^{im} \cdot w \cdot L_i^D + f_K^{im} \cdot r \cdot K_i^D + f_M^{im} \cdot p_m \cdot M_i + f_T^{im} \cdot NTX_i + PSFIX_v^{im} = PM_{mi}^v \quad \text{3.1-4. Equation}$$

$$f_Y^{im} \cdot \theta_Y^{im} \cdot Y_i + \sum_j^J f_{xj}^{im} \cdot \theta_{xj}^{im} \cdot X_i^j + f_L^{im} \cdot \theta_L^{im} \cdot L_i^D + f_K^{im} \cdot \theta_K^{im} \cdot K_i^D + f_M^{im} \cdot \theta_M^{im} \cdot M_i + PSFIX^{im} = PM_{mi} \quad \text{3.1-5. Equation}$$

$$PM_{mi} < \min\left(PM_{mi}^{fix}, PM_{mi}^{voll}, PM_{mi}^{vold}, PM_{mi}^{mixl}, PM_{mi}^{mixd}\right) \quad \text{3.1-6. Equation}$$

$$PM_{mi}^v < \min\left(PM_{mi}^{fix}, PM_{mi}^{vall}, PM_{mi}^{vald}, PM_{mi}^{mixl}, PM_{mi}^{mixd}\right) \quad \text{3.1-7. Equation}$$

The technological set of the enterprise is highly detailed, contains the four types of input, each in seven different forms. There are inner services used for the production of other services, as well as services offered by the payment service providers and services used for the final execution of payments. The technological set can be separated into consumption good production and payment execution production.

3.1.1. Cost structure of consumption good production

The final consumption good's production function is a composition of Leontief and CES type functions. For capital and labour there exists a level of substitution, but for intermediate consumption and imports we use fixed ratios. The parameters are calibrated using SNA statistics.

The production function can be given as the following. The AL_i^y and AK_i^y are the CES parameters, the A_x^i and the A_m are the Leontief ratios.

$$Y_i = \min\left(\left(AL_i^y \cdot L_i^{Dyv^{-\sigma_i}} + AK_i^y \cdot K_i^{Dyv^{-\sigma_i}}\right)^{-\frac{1}{\sigma_i}}, \cdots, A_x^i \cdot X_i^y, \cdots, A_m \cdot M^y\right) \quad \text{3.1-8. Equation}$$

3.1.2. Cost and demand structure of payment service production

In the case of payment service production, we use a more detailed production function for all four types of inputs. The detailed production function was estimated with data from the Hungarian social cost of payments (COP) study and – unlike the normal real goods' production function – is not homogenous of degree one. This means that unlike the usual theory well defined demand functions can exist for most input markets and in some cases the supply function is defined. Since it is not true for all cases, we modelled the HUPS model as a demand driven disequilibrium model and do not formally include the supply functions.

Based on payment method shares and average transaction values, we can compute the needed amount of payment method execution in volumes and values for every payment method (PM_{mi}^{v}). We use f_R^{im} to represent the share of the m-th payment method in the overall turnover of the input category represented by R {L, K, M, X}. The following equations states that the needed value of the relevant payment service is the value needed to accept payments for outputs, pay for intermediate consumption, labour, capital and import, pay taxes and a not explained fix part. The second equation transforms the values to volumes using the reciprocal of the average value per transaction θ_R^{im} .

$$f_Y^{im} \cdot p_i \cdot Y_i + \sum_j^J f_{xj}^{im} \cdot p_j \cdot X_i^j + f_L^{im} \cdot w \cdot L_i^D + f_K^{im} \cdot r \cdot K_i^D + f_M^{im} \cdot p_m \cdot M_i + f_T^{im} \cdot NTX_i + PSFIX_v^{im} = PM_{mi}^v \qquad \text{3.1-9. Equation}$$

$$f_Y^{im} \cdot \theta_Y^{im} \cdot Y_i + \sum_j^J f_{xj}^{im} \cdot \theta_{Xj}^{im} \cdot X_i^j + f_L^{im} \cdot \theta_L^{im} \cdot L_i^D + f_K^{im} \cdot \theta_K^{im} \cdot K_i^D + f_M^{im} \cdot \theta_M^{im} \cdot M_i + PSFIX^{im} = PM_{mi} \qquad \text{3.1-10. Equation}$$

Based on the data of the COP study, we distinguish between seven types of costs in the management and execution of payments. The detailed cost structure is essential in modelling the change in costs and resource usage with shifts in payment behaviours. Of course, not every payment service uses all seven types of cost, but in this way we can model the cost structure of cardinally different services.

To produce payment methods the firm spends its own resources. The straightforward definition of the technological set is complicated because of the multiple levels of nested Leontief and polynomial functions. To produce the desired amount of payment transaction volume and value all the necessary related cost types are used.

$$PM_{mi} < \min\left(PM_{mi}^{fix}, PM_{mi}^{voll}, PM_{mi}^{vold}, PM_{mi}^{mixol}, PM_{mi}^{mixod}\right) \qquad \text{3.1-11. Equation}$$

$$PM_{mi}^{v} < \min\left(PM_{mi}^{fix}, PM_{mi}^{vall}, PM_{mi}^{vald}, PM_{mi}^{mixal}, PM_{mi}^{mixad}\right) \qquad \text{3.1-12. Equation}$$

It means that in optimal solution the following applies:

$$PM_{mi} = PM_{mi}^{voll} = PM_{mi}^{vold} = PM_{mi}^{mixol} = PM_{mi}^{mixod} < PM_{mi}^{fix} \qquad \text{3.1-13. Equation}$$

$$PM_{mi}^{v} = PM_{mi}^{vall} = PM_{mi}^{vald} = PM_{mi}^{mixal} = PM_{mi}^{mixad} < PM_{mi}^{fix} \qquad \text{3.1-14. Equation}$$

This means in overall seven different type of cost exist of which two is not unique for volumes and values.

3.1.2.1. Fix cost

Nearly all payment service production has some kind of fix cost, namely the costs of management associated with the given transaction type – if the allocation can be made in the first place – or the capital costs – and amortisation – of the basic infrastructure. These costs cannot be allocated to volumes or values, so some kind of simplification is needed. If the cost is just for inner allocation, then professional estimations are made based on the data of the COP study. In other cases, for the PSPs the allocation can decidedly affect the pricing routine. In those cases, more sophisticated secondary fixed cost allocation estimations are made so it reflects the observed pricing routine more accurately.

$$PM_{mi}^{fix}=\begin{cases} if\ \min\left(\frac{X_{mi}^{f}}{A_{xmi}^{f}},\frac{L_{mi}^{f}}{A_{lmi}^{f}},\frac{K_{mi}^{f}}{A_{kmi}^{f}},\frac{M_{mi}^{f}}{A_{mmi}^{f}}\right)<1 \quad PM_{mi}^{fix}=0 \\ if\ \min\left(\frac{X_{mi}^{f}}{A_{xmi}^{f}},\frac{L_{mi}^{f}}{A_{lmi}^{f}},\frac{K_{mi}^{f}}{A_{kmi}^{f}},\frac{M_{mi}^{f}}{A_{mmi}^{f}}\right)\geq 1 \quad PM_{mi}^{fix}=\infty \end{cases}$$ 3.1-15. Equation

3.1.2.2. Volume-based variable costs

If a given variable cost changes with and only with the number of transactions, then the allocation can easily be made. In a linear case, we use a Leontief production function. If the study showed that the cost is degressive and has some economies of scale then a polynomial is used. The power is calibrated to reflect the degree of homogeneity estimated by the COP study.

$$PM_{mi}^{voll}=\min\left(\frac{X_{mi}^{voll}}{A_{xmi}^{voll}},\frac{L_{mi}^{voll}}{A_{lmi}^{voll}},\frac{K_{mi}^{voll}}{A_{kmi}^{voll}},\frac{M_{mi}^{voll}}{A_{mmi}^{voll}}\right)$$ 3.1-16. Equation

$$PM_{mi}^{vold}=\min\left(\left(\frac{X_{mi}^{vold}}{A_{xmi}^{vold}}\right)^{\frac{1}{\delta_{rmi}^{vold}}},\left(\frac{L_{mi}^{vold}}{A_{lmi}^{vold}}\right)^{\frac{1}{\delta_{rmi}^{vold}}},\left(\frac{K_{mi}^{vold}}{A_{kmi}^{vold}}\right)^{\frac{1}{\delta_{rmi}^{vold}}},\left(\frac{M_{mi}^{vold}}{A_{mmi}^{vold}}\right)^{\frac{1}{\delta_{rmi}^{vold}}}\right)$$ 3.1-17. Equation

3.1.2.3. Value-based variable costs

In this case, the reported variable cost only changes with the value of the executed payment. As with the volume-based costs, we use Leontief and polynomial functions to reflect the degree of homogeneity observed.

$$PM_{mi}^{vall}=\min\left(\frac{X_{mi}^{vall}}{A_{xmi}^{vall}},\frac{L_{mi}^{vall}}{A_{lmi}^{vall}},\frac{K_{mi}^{vall}}{A_{kmi}^{vall}},\frac{M_{mi}^{vall}}{A_{mmi}^{vall}}\right)$$ 3.1-18. Equation

$$PM_{mi}^{vald}=\min\left(\left(\frac{X_{mi}^{vald}}{A_{xmi}^{vald}}\right)^{\frac{1}{\delta_{rmi}^{vald}}},\left(\frac{L_{mi}^{vald}}{A_{lmi}^{vald}}\right)^{\frac{1}{\delta_{rmi}^{vald}}},\left(\frac{K_{mi}^{vald}}{A_{kmi}^{vald}}\right)^{\frac{1}{\delta_{rmi}^{vald}}},\left(\frac{M_{mi}^{vald}}{A_{mmi}^{vald}}\right)^{\frac{1}{\delta_{rmi}^{vald}}}\right)$$ 3.1-19. Equation

3.1.2.4. Mixed cost structures

In some cases, we cannot allocate the variable costs entirely to volumes or solely to values because they change with both of them. If a cost is based on both sides the fix cost secondary allocation applies.

$$\sqrt{PM_{mi}^{mixol}\cdot PM_{mi}^{mixal}}=\min\left(\frac{X_{mi}^{mixl}}{A_{xmi}^{mixl}},\frac{L_{mi}^{mixl}}{A_{lmi}^{mixl}},\frac{K_{mi}^{mixl}}{A_{kmi}^{mixl}},\frac{M_{mi}^{mixl}}{A_{mmi}^{mixl}}\right)$$ 3.1-20. Equation

$$\sqrt{PM_{mi}^{mixod}\cdot PM_{mi}^{mixad}}=\min\left(\left(\frac{X_{mi}^{mixd}}{A_{xmi}^{mixd}}\right)^{\frac{1}{\delta_{rmi}^{mixd}}},\left(\frac{L_{mi}^{mixd}}{A_{lmi}^{mixd}}\right)^{\frac{1}{\delta_{rmi}^{mixd}}},\left(\frac{K_{mi}^{mixd}}{A_{kmi}^{mixd}}\right)^{\frac{1}{\delta_{rmi}^{mixd}}},\left(\frac{M_{mi}^{mixd}}{A_{mmi}^{mixd}}\right)^{\frac{1}{\delta_{rmi}^{mixd}}}\right)$$ 3.1-21. Equation

But since the model does not use directly the technological sets, we give the solutions and demand functions which describe the behaviour of the different agents. The 7 equations for (R={X,M,L,K}):

$$R_{mi}^{fix}=A_{mi}^{fix}$$ 3.1-22. Equation

$$R_{mi}^{voll}=A_{rmi}^{voll}\cdot PM_{mi}$$ 3.1-23. Equation

$$R_{mi}^{vold}=A_{rmi}^{vold}\cdot\left(PM_{mi}\right)^{\delta_{rmi}^{vold}}$$ 3.1-24. Equation

$$R_{mi}^{vall} = A_{rmi}^{vall} \cdot PM_{mi}^{v}$$ 3.1-25. Equation

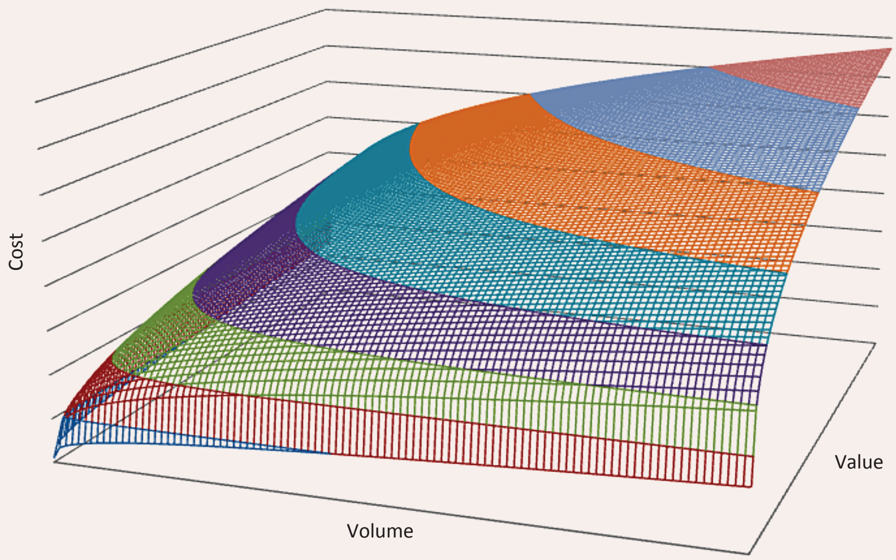
$$R_{mi}^{vald} = A_{rmi}^{vald} \cdot \left(PM_{mi}^{v}\right)^{\delta_{rmi}^{vald}}$$ 3.1-26. Equation

$$R_{mi}^{mixl} = A_{rmi}^{mixl} \cdot \sqrt{PM_{mi} \cdot PM_{mi}^{v}}$$ 3.1-27. Equation

$$R_{mi}^{mixl} = A_{rmi}^{mixl} \cdot \sqrt{PM_{mi} \cdot PM_{mi}^{v}}^{\delta_{rmi}^{mixd}}$$ 3.1-28. Equation

By multiplying the given demand functions with the costs of the related inputs we can create a cost surface for payment services production depending on the volume and value of the produced transactions (Chart 4). The cost surface is differentiable and continuous – except for the quasi-fix costs – but not homogenous of degree one.

Chart 4
Cost surface of volume/value of payment transactions



Usually executing a transaction in a payment method requires the use of some payment services from the payment service providers. In general term the coefficient is one – one credit transfer execution as a payment method needs the payment service for one credit transfer service from the banks – but not in all cases, most notably cash management. The following equations state the required amount from the different payment services (PS_{mi}^{D}) with the estimated ratio A_{mi}^{vol} for volumes and values.

$$PM_{mi} = \min\left(A_{mi}^{vol} \cdot PS_{mi}^{D}, \cdots,\right)$$ 3.1-29. Equation

$$PM_{mi}^{v} = \min\left(A_{mi}^{val} \cdot PS_{mi}^{Dv}, \cdots,\right)$$ 3.1-30. Equation

The model employs different types of taxes; value added tax *(VAT)*, taxes on wages *(TXL)*, taxes on capital income *(TXK)*, net transfers *(OTX_i)* and taxes on output value *(TXY)*.

$$VAT \cdot \left(p_i \cdot Y_i - \sum_{j}^{I} p_j \cdot X_i^j - p_m \cdot M_i\right) + r \cdot K_i^D \cdot TXK + TXL \cdot w \cdot L_i^D + OTX_i + TXY \cdot p_i \cdot Y_i = NTX_i$$ 3.1-31. Equation

3.1.3. Real production pricing

The pricing routine calculates with total costs of the used resources, which incorporates payment management costs and taxation. The taxation costs include the costs of paying taxes (λ^8) and the payment execution costs which are volume (λ_g^4) and value-based (λ_g^5) are both converted to calculate the total average costs. The optimal pricing routine is the following:

$$p_i = \sum_j^n p_j^T a_j^i + w_i^T \cdot \frac{L_i^{Dy}}{Y_i} + r_i^T \cdot \frac{K_i^{Dy}}{Y_i} + p_m^T \cdot a_{mi} + \sum_g^k \lambda_g^4 \cdot \left(f_Y^{ig} \cdot \theta_y^{ig} + \sum_i^n f_{xi}^{ig} \cdot \theta_{Xi}^{ig} \cdot a_j^i \right)$$
$$+ \sum_g^k \lambda_g^5 \cdot \left(f_Y^{ig} \cdot p_i + \sum_i^n f_{xi}^{ig} \cdot a_j^i \cdot p_i \right) + \lambda^8 \cdot VAT \cdot \left(p_i - \sum_i^n p_i a_j^i \right) + \lambda^8 \cdot TXY \cdot p_i \quad \text{3.1-32. Equation}$$

The shadow costs represent the full costs of the use of resources. λ for the index 1-2-3 represents the total costs for the primary inputs, we use the denotation w_i^T, r_i^T and $p_{m_i}^T$ for labour, capital and imports. The 6th and 7th shadow cost is an auxiliary variable for the cash-electronic transformation cost module; the 8th is the total cost of paying taxes.

The biased costs of intermediate consumption and inputs are the following. The costs are augmented with the costs of executing the related payment, for example in the case of labour cost – wages (*W*) – the total labour cost is the base wage, the cost of executing the nominal value of salary payments, the same costs for volumes and the taxes on labour corrected with taxation shadow costs.

$$p_{j_i}^T = p_j + \sum_m^M \lambda_{im}^4 \cdot f_X^{im} \cdot \theta_M^{im} + \sum_m^M \lambda_{im}^5 \cdot f_X^{im} \cdot p_j + \lambda_i^8 \cdot TXX \cdot p_j \quad \text{3.1-33. Equation}$$

$$w_i^T = w + \sum_m^M \lambda_{im}^4 \cdot f_L^{im} \cdot \theta_L^{im} + \sum_m^M \lambda_{im}^5 \cdot f_L^{im} \cdot w + \lambda^8 \cdot TXL \cdot w \quad \text{3.1-34. Equation}$$

$$r_i^T = r + \sum_m^M \lambda_{im}^4 \cdot f_K^{im} \cdot \theta_K^{im} + \sum_m^M \lambda_{im}^5 \cdot f_K^{im} \cdot r + \lambda_i^8 \cdot TXK \cdot r \quad \text{3.1-35. Equation}$$

$$p_{m_i}^T = p_m + \sum_m^M \lambda_{im}^4 \cdot f_M^{im} \cdot \theta_M^{im} + \sum_m^M \lambda_{im}^5 \cdot f_M^{im} \cdot p_m + \lambda_i^8 \cdot TXM \cdot p_m \quad \text{3.1-36. Equation}$$

To calculate the total cost firstly the total cost of payments are calculated. The costs are biased by the exogenous, fix volume and value which cannot be explained by flow variables of the model, to represent the total services used.

$$\lambda_{im}^4 = \left(\varphi_m + w_i^T \cdot \frac{L_{mi}^{Dp}}{PS_{mi}^D} + r_i^T \cdot \frac{K_{mi}^{Dp}}{PS_{mi}^D} + p_{m_i}^T \cdot am_{mi} + \sum_i p_{xi}^T \cdot ax_{xi} \right) \cdot \frac{PS_{mi}^D}{PS_{mi}^D - PSFIX^{im}} \quad \text{3.1-37. Equation}$$

$$\lambda_{im}^5 = \left(\varphi_m^v + w_i^T \cdot \frac{L_{mi}^{Dpv}}{PS_{mi}^{Dv}} + r_i^T \cdot \frac{K_{mi}^{Dpv}}{PS_{mi}^{Dv}} + p_{m_i}^T \cdot am_{mi}^v + \sum_i p_{xi}^T \cdot ax_{xi}^v \right) \cdot \frac{PS_{mi}^{Dv}}{PS_{mi}^{Dv} - PSFIX_v^{im}} \quad \text{3.1-38. Equation}$$

Taxation execution costs are extremely simple because in our model it only depends on values. We use the simplification that higher taxation does not result in more transaction.

$$\lambda_i^8 = 1 + \sum_m^M f_T^{im} \cdot \lambda_{im}^5 \quad \text{3.1-39. Equation}$$

3.2. PAYMENT SERVICE PROVIDERS

Based on the data of the COP study we designed the PSPs' equations to fit every kind of payment service providers, even if they produce a huge amount of services – like the banking sector – or just one – like the Cash-in-transit corporations. The following equations form a set which is applied to every PSP agent in the model.

The payment service providers have a profit maximisation problem described in the profit equation. Because of the high degree of cross pricing and oligopoly competition, the profit will not be necessarily zero.

$$\pi^{psp} = \sum_{m \in psp}^{M} \left(\varphi_m \cdot PS_m^{St} + \varphi_m^v \cdot PS_m^{Sv} \right) - w \cdot L_{psp}^D - r \cdot K_{psp}^D - NTX_{psp} - \sum_i^J p_i \cdot X_i^{psp} - \sum_m^M \left(\varphi_m \cdot PS_m^{Dt} + \varphi_m^v \cdot PS_m^{Dv} \right) \quad \text{3.2-1. Equation}$$

Bounded by,
Definition of net taxes:

$$NTX_{psp} = L_{psp}^D \cdot w \cdot TXL + K_{psp}^D \cdot r \cdot PTX + Y_{psp} \cdot TXY + OTX_{psp} \quad \text{3.2-2. Equation}$$

Production set:

$$PM_{mpsp} = \min\left(PM_{mpsp}^{fix}, PM_{mpsp}^{voll}, PM_{mpsp}^{vold}, PM_{mpsp}^{mixl}, PM_{mpsp}^{mixd} \right) \quad \text{3.2-3. Equation}$$

$$PM_{mi}^v = \min\left(PM_{mpsp}^{fix}, PM_{mpsp}^{vall}, PM_{mpsp}^{vald}, PM_{mpsp}^{mixl}, PM_{mpsp}^{mixd} \right) \quad \text{3.2-4. Equation}$$

The output of a PSP is the transaction volume and value of the created payment service and to produce the offered services they use labour, fixed capital, intermediate production, imports and other payment services.

To simplify the model, we do not calculate the cost of payments of the payment service providers. Inserting this into the model would greatly increase its complexity, but it would not affect the results significantly since the total cost of paying wages and proprietary income is minimal for a banking institution.

$$w_{psp}^T = w + w \cdot TXL \quad \text{3.2-5. Equation}$$

$$r_{psp}^T = r + r \cdot PTX \quad \text{3.2-6. Equation}$$

The total income of the payment service provider is made up of all revenues based on volume and value.

$$Y_{psp} = \sum_{m \in psp}^{M} \left(\varphi_m \cdot PS_m^{St} + \varphi_m^v \cdot PS_m^{Sv} \right) \quad \text{3.2-7. Equation}$$

The payment service providers pay taxes based on labour usage, return on capital and – in case of Hungary's financial transaction tax – taxes based on payment transaction volumes and values.

$$NTX_{psp} = L_{psp}^D \cdot w \cdot TXL + K_{psp}^D \cdot r \cdot PTX + Y_{psp} \cdot TXY + OTX_{psp} \quad \text{3.2-8. Equation}$$

The production of the offered services is given by the same technological structure as the inner costs of executing payments for corporations and households.

$$PM_{mpsp} < \min\left(PM_{mpsp}^{fix}, PM_{mpsp}^{voll}, PM_{mpsp}^{vold}, PM_{mpsp}^{mixl}, PM_{mpsp}^{mixd} \right) \quad \text{3.2-9. Equation}$$

$$PM_{mi}^v < \min\left(PM_{mpsp}^{fix}, PM_{mpsp}^{vall}, PM_{mpsp}^{vald}, PM_{mpsp}^{mixl}, PM_{mpsp}^{mixd} \right) \quad \text{3.2-10. Equation}$$

The solution for (R={X,M,L,K}).

$$R_{mpsp}^{fix} = A_{mpsp}^{fix} \quad \text{3.2-11. Equation}$$

$$R_{mpsp}^{voll} = A_{mpsp}^{voll} \cdot PM_{mpsp}$$ 3.2-12. Equation

$$R_{mpsp}^{vold} = A_{rmpsp}^{vold} \cdot \left(PM_{mpsp}\right)^{\delta_{rmpsp}^{vold}}$$ 3.2-13. Equation

$$R_{mpsp}^{vall} = A_{rmpsp}^{vall} \cdot PM_{mpsp}^{v}$$ 3.2-14. Equation

$$R_{mpsp}^{vald} = A_{rmpsp}^{vald} \cdot \left(PM_{mpsp}^{v}\right)^{\delta_{rmpsp}^{vald}}$$ 3.2-15. Equation

$$R_{mpsp}^{mixl} = A_{rmpsp}^{mixl} \cdot \sqrt{PM_{mpsp} \cdot PM_{mpsp}^{v}}$$ 3.2-16. Equation

$$R_{mpsp}^{mixd} = A_{rmpsp}^{mixd} \cdot \sqrt{PM_{mpsp} \cdot PM_{mpsp}^{v}}^{\,\delta_{rmpsp}^{mixd}}$$ 3.2-17. Equation

Using the detailed technological structure of the payment service, the PSP calculates the total direct cost that can be allocated to transaction values or volumes. In a competitive market environment, the fix costs would be allocated in a given way and the pricing routine would be complete. But in Hungary we observe a high degree of oligopoly behaviour, cross pricing between different payment methods and a more complex adaptation to outside cost shocks – such as changes in taxation. Based on our numerous studies, we calibrated the pricing routine of the different payment service providers – most notably the banking sector.

To simplify future equations, the definition of direct costs (DC_m^g):

$$DC_m^g = PS_m^{Sg} \cdot TXY + w_{psp}^{T} \cdot L_{pspm}^{Dg} + r_{psp}^{T} \cdot K_{pspm}^{Dg} + p_i \cdot X_{im}^{Dg} + \sum_{m \notin psp}^{M} \varphi_m \cdot PS_m^{Dpsp}$$ 3.2-18. Equation

3.2.1. Pricing methods of PSPs

The PSP uses a mark-up profit on allocated costs ($markup^{psp}$) – which include the direct costs and the share of fix costs (ω_{pspm}^{fg}) allocated to the volume or value of transactions.

$$\varphi_m^g = \left(1 + markup^{psp} + cross_m^{pspg}\right) \cdot \frac{\left(DC_m^g + \omega_{pspm}^{fg} \cdot \left(r_{psp}^{T} \cdot K_{pspm}^{Dfg} + w_{psp}^{T} \cdot L_{pspm}^{Dfg}\right)\right)}{PS_m^{Sg}}$$ 3.2-19. Equation

The cross pricing rate ($cross_m^{pspg}$) is defined to match the calibrated amount of pushed over costs from other services. Using this definition, the net profit of the payment service provider does not change with changes in payment habits, which indicates a certain type of adaptation process. The payment service provider modifies the cross-pricing margin in a way that the net profit margin of all activities remains constant for every payment behaviour change.

$$cross_m^{pspg} \cdot \left(DC_m^g + \omega_{pspm}^{fg} \cdot \left(r_{psp}^{T} \cdot K_{pspm}^{Dfg} + w_{psp}^{T} \cdot L_{pspm}^{Dfg}\right)\right) = cross_m^{pspg0} \cdot \left(DC_m^{g0} + \omega_{pspm}^{fg} \cdot \left(r_{psp}^{T0} \cdot K_{pspm}^{Dfg0} + w_{psp}^{T0} \cdot L_{pspm}^{DFG0}\right)\right)$$ 3.2-20. Equation

The definition for the cross-pricing rate states that the nominal value of the costs that are allocated to other activities remains the same in every case. This means that the PSP biases the final prices to allocate the same amount as in the starting point ($cross_m^{pspg0}$).

3.3. CENTRAL AND LOCAL GOVERNMENTS

One of the primary focuses of the model is to calculate effects of technological and cost shocks. Changes in taxation are the basic cost shock that the model can calculate. For this reason, the central and local government – commonly referred from now on as the public sector, not including the public companies and the national bank – is detailed to incorporate these effects.

Apart from being a pivotal agent in collecting taxes and modifying the cost structure of the different agents, the public sector also uses payment services intensively to execute its own payments. Taxation, state subsidies, pension payments and other cash incomes and outward payments are all included in the model. Since the production side of the public sector is in the non-monetary enterprises, sector payments related to employment are executed in the relevant sector.

The HUPS model can be used to calculate the total tax effect of different payment system policies. Based on this, we do not take into account any behavioural function of the public sector. The government has a given Leontief consumption structure which is rigid. The starting amount of the budget deficit is taken as an outside variable, apart from it the government spends as much as it collects from taxes.

The expenditures (G_E) and the revenues (G_R) of the central and local government agent equals naturally in the model.

$$G_R = G_E \qquad \text{3.3-1. Equation}$$

The structure of governmental incomes is the following. The government's main income comes from the different taxes calibrated by the SNA tables of Hungary and the share of profit from the owned companies. Another part of the revenues is not explained and consists of different international transfers.

$$G_R = NTX_G + D_G + \pi^G \qquad \text{3.3-2. Equation}$$

$$NTX_G = \sum_i^J NTX_i + NTX_h + NTX_{row} + \sum_g^G NTX_{psp} \qquad \text{3.3-3. Equation}$$

$$\pi^G = \pi^{rtgs} + \omega_G^{ach} \cdot \pi^{ach} + \pi^{cl} + \pi^{ps} \qquad \text{3.3-4. Equation}$$

The structure of expenses, public consumption (C_G^D), transfers – social and capital transfers (TR_G) – and the starting level of deficit and costs of debt management (DP_G):

$$G_E = C_G^D + TR_G + DP_G \qquad \text{3.3-5. Equation}$$

$$C_G^D = G \cdot \sum_i^J p_i \cdot a_i^G + \sum_g^k \left(\varphi_m \cdot PS_{mg}^D + \varphi_m^v \cdot PS_{mg}^{Dv} \right) \qquad \text{3.3-6. Equation}$$

The execution of payments, volumes and values are in the usual form for expenditures and transfers:

$$PS_{mg}^D = \theta_m^G \cdot G \cdot f_m^G + \theta_m^{TR} \cdot TR_G \cdot f_m^{TR} + PSFIX^{gm} \qquad \text{3.3-7. Equation}$$

$$PS_{mg}^{Dv} = G \cdot f_g^G + TR_G \cdot f_m^{TR} + PSFIX_v^{gm} \qquad \text{3.3-8. Equation}$$

3.4. THE PROBLEM OF HOUSEHOLDS

The household sector is a standard utility maximisation agent with a detailed cost structure of payments execution. Households do not change their labour and capital supply in the HUPS model. We use the realistic assumption that no change in the payment services supply chain can significantly alter labour and capital supply and demand. This assumption can be relaxed but the results do not alter in any way.

The utility function of the consumer is given by the following formula:

$$U(C_i) = \left(A_1 \cdot C_1^{-\beta_h} + \cdots + A_J \cdot C_J^{-\beta_h} \right)^{-\frac{1}{\beta_h}} \qquad \text{3.4-1. Equation}$$

The budget restrictions:

$$\sum_{i}^{J} p_i \cdot C_i + \sum_{m}^{M}\left(\varphi_m \cdot PS_{mh}^{D} + \varphi_m^{v} \cdot PS_{mh}^{Dv}\right) + NTX_h = r \cdot K^S + w \cdot L^S + \pi^h + OTX_h \qquad \text{3.4-2. Equation}$$

$$\pi^h = \sum_{i}^{J} \pi_i^p + \sum_{m}^{M} \pi_m^{psp} \qquad \text{3.4-3. Equation}$$

$$C = \sum_{i}^{J} p_i \cdot C_i \qquad \text{3.4-4. Equation}$$

The necessary volume and value of the demanded payment services is calculated in the same way as for the other agents.

$$\sum_{i}^{J} \theta_{ch}^{i} \cdot f_{ch}^{i} \cdot p_i \cdot C_i + f_L^h \cdot \theta_L^h \cdot L_h^S + f_K^{im} \cdot \theta_K^h \cdot K_h^S + f_M^h \cdot \theta_M^h \cdot M_h^D + PSFIX^{mh} = PS_{mh}^{D} \qquad \text{3.4-5. Equation}$$

$$\sum_{i}^{J} f_{ch}^{i} \cdot p_i \cdot C_i + f_L^h \cdot L_h^S + f_K^{im} \cdot K_h^S + f_M^h \cdot M_h^D + PSFIX_v^{mh} = PS_{mh}^{Dv} \qquad \text{3.4-6. Equation}$$

The solution for consumption goods demand is derived from the CES function.

$$\frac{p_i \cdot C_i}{C} = \frac{\left(\sum_{j}^{J} A_j^{\beta_h} \cdot C_j^{1-\beta_h}\right)^{\frac{\beta_h}{1-\beta_h}}}{A_i^{\beta_h} \cdot C_i^{1-\beta_h}} \qquad \text{3.4-7. Equation}$$

The taxes on capital and labour income and a fix part not explained by the model:

$$NTX_h = HTXK \cdot r \cdot K^S + HTXL \cdot w \cdot L^S + NTX_{fix} \qquad \text{3.4-8. Equation}$$

The inner costs of payments execution in the case of households are solely labour needs since our surveys show that time cost is by far the most dominant inner cost of the different payment methods for households. Other types of costs are nearly negligible and are not fundamentally part of the total costs of payments.

$$PMI_{mh} = PS_{mh}^{D} \qquad \text{3.4-9. Equation}$$

$$a_L^h \cdot PMI_{mh} = L_{mh}^{D} \qquad \text{3.4-10. Equation}$$

The functions for the resource supplies are exogenous and constant. From the total labour supply we have to deduce the amount of time spent on payments.

$$K^S = K_0^S \qquad \text{3.4-11. Equation}$$

$$L^S = L_0^S - \sum_{m}^{M} L_{mh}^{D} \qquad \text{3.4-12. Equation}$$

3.5. Market equations

Labour market

$$L^S = L_i^D + L_{bs}^D + L_{ps}^D + L_{bkr}^D + L_{viber}^D + L_{kpl}^D \qquad \text{3.5-1. Equation}$$

Capital market

$$K^S + K_{row}^S = K_i^D + K_{bs}^D + K_{ps}^D + K_{bkr}^D + K_{viber}^D + K_{kpl}^D \qquad \text{3.5-2. Equation}$$

Real goods market

$$Y_i = \sum_j^I X_j^i + C_i + G \cdot a_i^G + X_i^{bs} + X_{bkr}^{Di} + X_{viber}^{Di} + X_{kpl}^{Di} + I_i$$ 3.5-3. Equation

Payment services markets

The payment service markets must be duplicated for value and volume of offered and demanded transactions.

$$PS_m^{St} = \sum_i^J PS_{mi}^D + PS_{mh}^D + PS_m^{Dbs} + PS_{mps}^D + PS_{mpc}^D + PS_{mcit}^D + PS_{mbkr}^D + PS_{mviber}^D + PS_{mkpl}^D + PS_{mg}^D$$ 3.5-4. Equation

$$PS_m^{Sv} = \sum_i^J PS_{mi}^{Dv} + PS_{mh}^{Dv} + PS_m^{Dbs} + PS_{mps}^{Dv} + PS_{mpc}^{Dv} + PS_{mcit}^{Dv} + PS_{mbkr}^{Dv} + PS_{mviber}^{Dv} + PS_{mkpl}^{Dv} + PS_{mg}^{Dv}$$ 3.5-5. Equation

3.6. EXOGENOUS VARIABLES

Because of the scope of the model, we do not expand the model with capital accumulation, non-rigid resource markets and changes in international trade. Most of the behavioural equation of the ROW sector and the not detailed sectors – auxiliary households sector – do not change with other parts of the model. These equations are used to close the model in a general equilibrium framework, but we do not believe that any change in the retail payment habits can significantly alter them.

$$M^S = M_0^S$$ 3.6-1. Equation

4. Information base and calibration of the model

The HUPS model is a complex computable general equilibrium model consisting of tens of thousands of equations. To satisfy the information requirements of the model, we have used numerous data sources, huge databases and most of the research output of recent years of the Financial Infrastructure Directorate of the MNB. The macro elements of the model are calibrated using various sources of the System of National Accounts and the payment statistics published by the MNB.

The micro foundations of the model are the numerous studies published by the MNB over the last years, most notably the cost of payments (COP) study. In this study, the MNB estimated the cost structure of the different agents in the retail payments supply chain, the different fees and transfers of money between the agents and finally the total social costs of the execution of payments in Hungary. The main focus of the COP study was the calculation of the social costs of payments. Because of that a high degree of aggregation was used in the published paper. But the data is available on a more disaggregated level which was essential to the calibration of the HUPS model.

Beside the macro statistics published by the MNB and the CSO (Central Statistical Office of Hungary) and the studies of the previous years, the model also uses data sources which represent the cutting edge of research studies in payment economics in the MNB. Most notably, the pricing routine of the payment service providers are calibrated using detailed, time series data of the Payment Services Pricing Monitoring System of the MNB. The payment behaviours of the agents are calculated based on the latest representative 1,000-sample household payment habit survey data of the MNB and the highly disaggregated data received from the Hungarian ACH's interbank clearing system and the RTGS of Hungary (VIBER).

The enormous information base of the HUPS model ensures that the results and conclusions are well founded and robust and can be applied to policy evaluation in Hungary.

4.1. PAYMENT STATISTICS

The HUPS model is based on three different statistical databases created and maintained by the MNB and the CSO. The volume and value statistics of the Hungarian payment system are collected by the MNB in a detailed method. Most of the payment methods in use in Hungary have a disaggregated statistical table for the type of sector initiating the transaction – corporate, household or other – the volume and turnover of transactions, and the channel in which the payment was initiated and made – e.g. paper or electronic or different kinds of terminals in the case of payment cards. The MNB also collects data by the value of the transactions from the ACH, which enables us to create detailed density functions for most of the payment methods.

The real economy part of the model is entirely SNA-based and is accessed from the CSO and Eurostat. These statistics provide the macro framework of the model, but are not unique to retail payment modelling. The base of the model is calibrated to 2010 and 2014. The 2010 data is used to integrate the COP study data, and a complete recalibration is made to ensure applicability – mainly the integration of important policy and fiscal measures taken since 2010.

These databases assure relevant information and data for all parts of the HUPS model. The calibration of the model is automated in a way that new statistical information is constantly added to the model which ensures that every policy evaluation uses the most recent available data.

4.2. COST OF PAYMENTS STATISTICS

In 2010, the Hungarian central bank published a detailed and comprehensive analysis of the retail payments services supply chain and calculated the social costs of payments in Hungary. The study found that the total cost of payments in Hungary amounts to more than 1.5% of GDP. The study also found that by switching to considerably more efficient payment habits close to 0.4% of GDP could be saved in costs. The MNB also calculated the average unit costs of the different payment methods and their profitability for the agents in the payment services supply chain.

The HUPS model builds on the same immense dataset collected for the COP study to model the inner technological sets of the payment service providers and the other sectors of the economy. Because the COP study has relevant data for 2010 and 2011, the HUPS technological base is calibrated to 2010. The changes in banking costs from 2010 are estimated from other statistics. It is safe to assume that the inner structure of costs – volume-based and value-based shares, degree of economies of scale – did not change significantly from 2010 to 2014. The pricing, fees and incomes of the different payment service providers are calibrated from other datasets which did not exist in the time of the COP study.

4.3. ADDITIONAL STATISTICAL INFORMATION

Apart from the standard macro statistical information and the information base of the COP study, the HUPS model uses two major data sets. To calibrate the detailed fee structure of the different payment services we used information from the newly created Payment Services Pricing Monitoring System. The system is based on the information of the entire fee condition list of every available payment account in Hungary and calculates average costs, prices for different segments and for the whole households sector. The fee condition lists are provided by the Hungarian PSPs for all of the payment accounts they open for their customers and the MNB has to be notified real-time of any changes in these condition lists. The monitoring system produces time series data which enable us to calibrate not just the price level of the payment services, but also the pricing behaviour of the agents.

The monitoring system has information starting from 2010 which is the base calibration of the model. The final calibrated version of the model uses the latest average prices available from the monitoring system. The data from the last four year is the sample to calibrate pricing routines.

The other crucial data source of the model is the information, studies and surveys of the last years regarding household and corporate payment habits in Hungary. The MNB performed surveys to collect data from households in 2010 and 2014 with a sample of 1,000 respondents. Apart from the surveys, the MNB has access to detailed information from the RTGS and the ACH's interbank clearing system.

4.4. SOLUTION OF THE MODEL

The HUPS model and its data relations are programmed in a Matlab r2014 environment. The size of the model does not allow us to solve it in the usual numerical analytic Newton-approximation methodology; the number of variables makes the calculation of a first order derivatives or the Hesse matrix impossible.

As a modelling tool, the HUPS model is programmed as a best-answer disequilibrium agent-based model. The stable points of the best-answer functions of the different agents are the same as the solutions of the original set of equations. The model has a number of solution algorithms to linearly stabilise the finite memory difference system of the model and create stable points for solution.

With this method, the extreme size of the model does not make it impossible to evaluate policy impacts even during daily analytical work.[1]

[1] The time need of the model runs differ greatly for the different scenarios, a slight change (1-5% of parameters) takes 20 to 30 minutes, but a significant change would increases running time to up an hour.

5. Baseline of the model

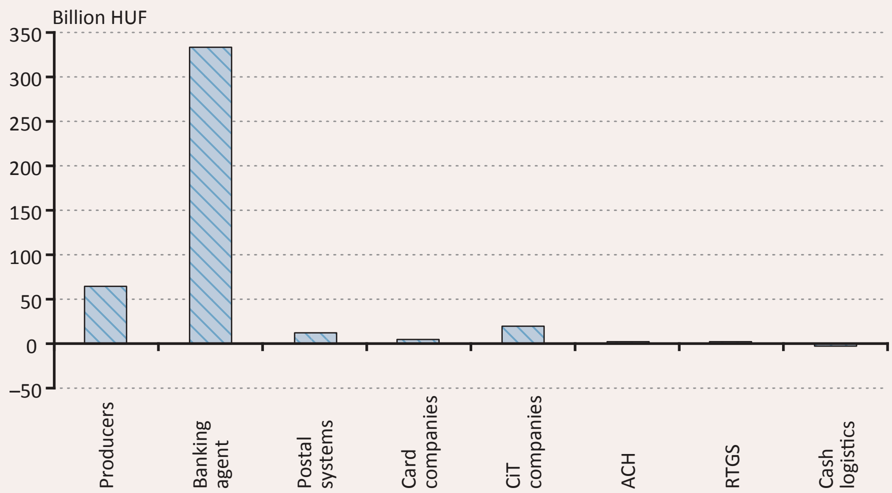
The HUPS model was calibrated to 2014 using the different data sources described in the previous chapter. The macro variables and parameters match the 2014 SNA integrated accounts for Hungary; the intermediate consumption structure was calibrated using the latest input-output table available for Hungary.

On the payment services supply chain side, the volumes and values derive from the MNB's payment statistics, while the prices of the different payment methods originate from the MNB's payment services pricing monitoring system. The calibration of the pricing algorithm – the level of cross pricing and monopolistic margin – is based on the COP study. The cost structure is also calibrated from the COP study adjusted to changes in resource prices and productivity growth of the sector.

5.1. SHARES OF BRANCHES OF ECONOMY

The payment services supply chain accounted for 1.6% of GDP in 2014 – or 2% of the total market output – and most of it concentrates in the banking sector (Chart 5). With the use of the model, we can calculate what the Hungarian economy would look like without cost of executing payments. This scenario resembles the hypothetical state of an economy mostly represented in theoretical modelling where the executions of payments are costless. In this scenario, **GDP would be 1.15% higher** than it is in 2014. The GDP increase is attributed to the reallocation of primary resources to other branches of economy, and since some agents in the payment services supply chain are more effective than the country average the effect is slightly less than the original share of the payment sector.

Chart 5
Gross value added of different agents in the payment services supply chain



5.2. PAYMENT BEHAVIOURS OF AGENTS

Hungary is a highly cash-intensive economy with most of the volume of retail payments executed in cash payments (Table 4). Credit transfers are fewer in numbers but make up several times GDP in Hungary in values. A considerable part of credit transfer transactions cannot be explained by a single economic act in the SNA framework and become exogenous, fixed in our model. On the other side, household consumption can be divided between the different payment methods. Approximately 50% of household consumption expenditure is in cash, the rest is covered by postal inpayment money orders and electronic (card, credit transfer and direct debit) transactions evenly.

Table 4
Volumes, values and shares of the primary payment methods

	Volume/value	Enterprises	Households	Other agents
Cash				
	3,134 mn pieces	6,36%	93,64%	0,00%
	58,547 bn HUF	84,38%	14,54%	1,08%
Credit transfer				
	289 mn pieces	36,23%	29,74%	34,03%
	544,596 bn HUF	52,30%	1,59%	46,11%
Payment card				
	359 mn pieces	0%	100%	0%
	2,664 bn HUF	0%	100%	0%

Because of the high number of transactions, cash payments are currently cheaper than card payments for household agents and acceptors as well. Payment card use imposes indirect cost on households through yearly card fees and cash became even cheaper due to the bimonthly free cash withdrawal opportunity in Hungary. On the merchants' side, cash acceptance is in average still cheaper than card acceptance (Table 5), although the gap closed considerably in recent years in the wake of the Hungarian interchange fee regulation.

Table 5
Shadow price of acceptance for different payment methods

Cash acceptance	49.9 HUF
Card acceptance	80.5 HUF
Direct debits	152.0 HUF
PIMO	145.7 HUF
Inward electronic credit transfer	2.9 HUF

5.3. FEE FLOW IN THE PAYMENT SERVICES SUPPLY CHAIN

In 2014, the total revenue in the payment services supply chain was HUF 536 bn, or 1.7% of GDP. Most of the fee payments go to the banking representative agent in the model for the execution of transactions and for fixed costs – account and card fees (Table 6). From the perspective of the banking agent's revenues, the real economy and households are nearly equally important. In the case of consumers, the fees are mostly fixed costs, on the other hand enterprises typically pay variable prices for the execution of payment transactions. Based on the monitoring system and the aggregate statistics, we can state that most of the variable fees are value-based costs. Since the producers execute payments of higher values than households, the average fees paid are generally proportionately higher.

Table 6
Fee revenues of different agents
(in HUF million)

Banking agent	479,448
from households	185,195
from other agents	24,431
from producers	269,821
Others agents	57,272
Total fee revenue	536,721

6. The model in use

In this chapter, we demonstrate the capabilities of the calibrated model by evaluating two retail payments related scenarios. The HUPS model is primarily designed to evaluate the effects of taxation, other kinds of policies, changes in pricing routines, long-term changes in consumer behaviour and the trade-off between different payment methods on the economy and the payment systems.

We first show the projected changes in the cost structures of the retail payment systems for the following years. We forecast the main trends of the retail payment segment in Hungary without policy intervention using a VAR model and analyse the expected effects on the different agents of the payment supply chain. This scenario shows the gains and losses in productivity and in social costs of operating the different payment systems as a consequence of the changes in the consumers' and corporate agents' payment habits.

Focusing on the acceptors' costs of cash and payment card transactions, in our second scenario we calculate the exact point where the cost of debit card acceptance generally becomes cheaper for the agents in Hungary than that of cash acceptance. This scenario shows the extra increase in payment card usage compared to the baseline that needs to be achieved by 2020 to reach this policy aim.

6.1. IMPACT OF EXPECTED CHANGES IN PAYMENT HABITS

In this scenario, we calculate a forecast of the structure of payment habits in Hungary for 2020 and use the HUPS model to evaluate how it will change the pricing of the different payment services. In this way, we can estimate how much of the gains that we calculated in Chapter 5.1 can be achieved in the following years without policy interventions.

For the forecast we used a VAR model to capture the long-term growth trends in volumes and values of the different payment transactions. The VAR model operates on three levels. The higher aggregates make up a standard VAR model which forecast the expected volume and value of the different payment methods. The lower aggregates calculate the expected change in the structure within a payment method, for example intra bank and domestic inter-bank transaction ratio and paper to electronic payment ratio. We selected a VAR model for this purpose not only because it is particularly useful for trend forecast, but because it will also be used for estimation of changes from the baseline. In the future this VAR model can help us also in calculating the estimated effect of different policy scenarios on the changes of payment habits, on the assumption that the basic relationship between these aggregates remain the same over the long run.

Using the VAR model and linear or exponential trends – based on best fitting – we created forecasts for 2020 (Table 7). The 6-7 year is most likely the longest plausible period for such kind of a forecast because our data regarding the payment habits in Hungary is not sufficient to prove that these trends and relations remain the same for 10-20 years. The long trends in the Hungarian payment infrastructure show a steady convergence to a more electronic, efficient payment system. The credit transfers are already in a high value per GDP, but still have a modest growth. Card payments have a much higher growth rate – in our forecast to 2020 the expected increase in volume reaches up to nearly 20% yearly.

Other payment methods, like the postal inpayment money order or paper-based transactions lose volume and value in the long run, eventually helping a more efficient system. Unfortunately, the direct debit forecast lacks the same optimism, the growing trend in the 2000s stopped in 2010 and no significant gains were achieved since then.

Table 7 Estimated average yearly growth rate of payment infrastructures and methods between 2014 and 2020			
		Volume	**Value**
Corporate	Number of accounts	–0.56%	
	Number of cards	–0.06%	
	Cash withdrawal	–6.59%	–3.60%
Households	Number of accounts	–1.70%	
	Number of cards	–0.06%	
	Card usage	19.26%	17.35%
	Cash withdrawal	–7.32%	4.28%
Entire economy	Credit transfer	2.95%	9.06%
	Credit transfer initiated in batch	1.52%	8.31%
	Direct debit	1.47%	0.77%
	Postal inpayment money order	–4.27%	–6.50%
	Pension payments by post	–5.50%	0.35%

For the real side of the economy, we use a technical long-term stable GDP growth rate and a productivity increase of 2% for the next 6 years. The trend for the real economy is important to anchor the per GDP values of the transaction and estimate a plausible scenario. Because the HUPS model is mainly created for retail payment economic policy evaluation, we do not make more assumptions for the real side of the economy. Because of this assumption, the productivity increase is even and general for all agents and all sectors and branches of the economy.

To anchor the long-term effects of the changes in payment behaviour, we calculate a baseline forecast for the model, which projects only the 2% increase of the economy, including also a 2% increase of the payment system without any structural change. This latter increase of the payment system is not trivial in our model, since the payment services production is not homogenous of degree one. This means, however, that if there are no behavioural changes, without this baseline forecast the general growth of the economy would decrease the relative share of the payment services supply chain in the economy over the long run, which is not feasible. This degressive feature of the production function is taken into account by the baseline forecast to which we compare all results of our first scenario in the following.

Table 8 Changes in macroeconomic variables	
Labour cost	0,17%
Capital cost	1,79%
GDP	0,48%

As shown in Table 8, the general change in the structure of payments habit has a positive effect on GDP. The costs of primary resources increase in real terms because of the increase in general productivity, which means that overall the long-term trends of the payment habits move in a desired direction, towards a more efficient payment system. The positive effect is observed despite the fact, that the share of the payment system supply chain does not drop in the first scenario compared to the baseline forecast; it is 1.85% of GDP.

The increase in productivity is the result of restructuring of primary resource allocation. The capital costs of the payment service production drop, due to a shift towards electronic payments from cash-based transactions. The agents operating these systems generally have higher productivity in capital – 3-4 gross value added (GVA) per capital unit compared to around 2 in real production – meaning the excess savings go towards real goods production.

Moving from the macroeconomic perspectives towards the individual services in the payment services supply chain, the real prices compared to the baseline varies greatly (Table 9). In the forecast for 2020 the credit transfers increase in total volume and value, but it is not true universally because paper-based transactions follow a downward trend while electronic transactions take their share. Because of that, their relative price changes accordingly. In the case of electronic transactions, there is a high degree of degressivity, an overall 19% increase in volumes for 2020 cause a 25-30% drop in average costs.

Table 9
Changes in total costs for the household agent

Credit transfers		
Paper	**Intra bank**	57.23%
	Inter bank	2.46%
Electronic	**Intra bank**	–23.22%
	Inter bank	–29.61%
Cash withdrawal		1.73%
Card yearly fee		57.64%
Direct debit		0.10%

Cash withdrawal costs do not deviate significantly from the baseline in this scenario. Due to the bimonthly free cash withdrawal opportunity, it is already priced below costs at a very small average fee. On average, consumers use less than the two withdrawals per month and that makes it harder to pass on significant increases in average costs to customers. On the other hand, despite payment card transactions being primarily – in an overwhelming share – free in Hungary, based on Ilyés et al. (2013) we can state that the payment service providers pass on their costs to yearly card fees. Thus, a huge increase in usage and costs increases payment card fees significantly in the long run. As stated before, direct debits have a very stable volume and value trend that does not alter pricing decisively in the long run.

Table 10
Changes in acceptor's cost
(per volume)

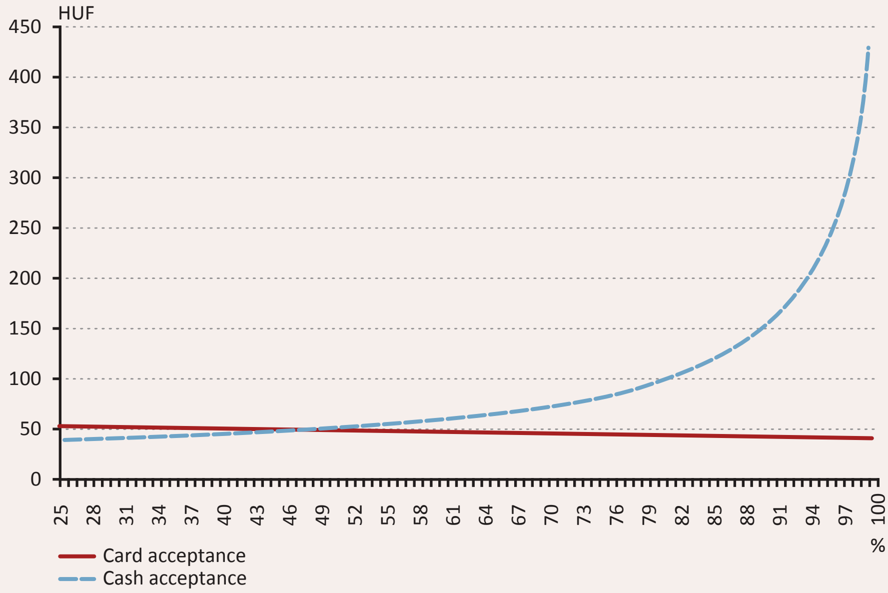
	Original structure	New cost structure
Cash payment acceptance	49.9 HUF	42.1 HUF
Credit transfer inward	2.9 HUF	2.8 HUF
Direct debit inward	152.0 HUF	166.7 HUF
PIMO inward	145.7 HUF	379.4 HUF
Card acceptance	80.5 HUF	51.0 HUF

The high growth rate of payment card transactions results in a significant drop in the cost of acceptance (Table 10). Cash use in Hungary still follows an upward trend, but smaller than card payments. The gap between the cost of cash and card acceptance starts to close in our scenario from 30 HUF to 17 HUF, but does not close completely. Based on the forecasts of the VAR model and the calculations of the HUPS model, by 2020 accepting cash will still be cheaper than accepting a card on average. Cash acceptance is becoming cheaper due to the still increasing volume and value of transactions.

6.2. TIPPING POINT OF CASH AND CARD ACCEPTANCE COSTS

In the first scenario, we demonstrated that in the current forecasts for 2020 the cost of accepting card payment will in average still be higher than that of cash-based transactions. In this scenario, we calculate the exact tipping point using the 2020 scenario as a baseline. For policy intervention purposes it is important to analyse how many of the cash transactions need to be transformed into payment card transactions for the two payment method to change places. As we can see in Chart 6, increasing the share of volumes of card transactions in households' retail payment situations makes cash transactions gradually more expensive, but only slightly diminishes the costs of card acceptance per volume. This is the result of the already high growth rate for card use. In the calibrated 2014 baseline of the HUPS model, the card acceptance cost is 80 HUF on average. For 2020, huge increases in use already decrease costs to 51 HUF on average. On the other side, the hypothetical significant drop in the volume of cash transactions means that the mostly fix costs of the cash infrastructure would fall on less transactions, exponentially increasing the average cost.

Chart 6
Changes in acceptor's shadow cost
(per volume)



Horizontal axis: share of card payments in households' payment transactions

The result of the second scenario shows that we reach the tipping point when households use their payment cards in around 40% of their payment transactions (Chart 6). In the 2020 forecast which we use as a baseline, the card share start from 25% of retail transactions or 1.03 bn transactions. The 2020 forecast already represents a significant increase in volume and value compared to the 2014 baseline, but to reach the tipping point in 2020 the 19% yearly growth rate projected from current trends would have to be increased to 30%. This would mean 740 million additional card transaction at the cost of cash payments by 2020 (Table 11).

Table 11
Changes in card and cash usage in the different scenarios

		2014	2020 forecast	Tipping point
Cash	**mn. pieces**	2,935	3,208	2,469
	mn. HUF	8,512,448	9,301,782	7,162,093
Card	**mn. pieces**	359	1,034	1,772
	mn. HUF	2,664,351	6,957,709	9,097,398

Chart 6 also shows that the increase in the average cost of cash acceptance is hyperbolic and its derivative becomes significant at the tipping point. Once card acceptance becomes cheaper, the decrease in relative use of cash makes every cash transaction more and more expensive.[2]

6.3. CONCLUSIONS OF THE SCENARIO ANALYSES

The two described scenarios show the inner workings of the model. A change in payment habits modifies individual demand and supply which in turn affects the actual market price through the non-linear production function and non-competitive pricing. Through price iteration the agents reallocate primary resources to other activities and a new equilibrium is reached.

In the first scenario, we showed what an effect a projected change in the payment habits would have on the economy and the payment system. Using the HUPS model we can state that the general direction of the trends in payment habits is positive – a more electronic system – but in 5-6 years Hungary will still be far from the European economies with the most advanced payment systems. Because of that, the cost advantage of cash acceptance will not disappear for 2020.

In the second scenario, we calculated the needed amount of intervention that would nullify this still existing cost advantage of cash acceptance. Based on the results of the HUPS model an additional significant 70% increase is needed in the number of payment card transactions at the cost of cash payments to reach that goal. This means that the already very impressive 19% average yearly growth rate in the number of payment card transactions, which we forecasted from the current trends, should be increased up to 30% for the 2014-2020 period.

[2] The reason for the cost of cash acceptance becoming not infinitely large close to the 100 % share is that agents of the real economy do execute cash payments between each other. These transactions are not included in this scenario.

7. Possible future extensions of the model

The first version of the HUPS model which is published in this paper is already suitable for in-depth and robust policy evaluation, but it is being further extended to incorporate new modules and be able to give a more detailed aspect of the economy.

7.1. NEW AGENTS AND ACTIVITIES

Inserting the payment system supply chain into a general equilibrium model can greatly increase the size of the model which has to be kept in mind with any extensions. Defining new payment methods in the HUPS system e.g. does not only add one more variable but up to one hundred related secondary variables. Defining a new agent has an even more significant effect on the size of the model. For example adding one more branch of the economy would add hundreds of new variables.

The HUPS model in this version employs 15 branches of economy and 82 activities and services related to the payment services supply chain. The basic data on which the model is based is a 65 branch disaggregated input-output table published every 5 years by the Hungarian Statistical Office. The level of aggregation in this model was chosen to reflect the different payment behaviours of the different branches of economy. However, the model is flexible and a lower level of aggregation is possible if the necessary detailed payment statistics are available.

Some payment methods and services in the model exist only in an aggregated form and a few small-scale payment methods are not inserted at all. Further disaggregation, and more payment services and more inner activities are being inserted to the HUPS model with every extension. The COP study of the MNB differentiated significantly more activities, which we decided to aggregate, but the MNB plans to revisit this theme and gather new information on the costs of payments. A new COP study will make the technological sets of the different agents more sophisticated and will provide up-to-date information about the costs of the different activities in the payment services supply chain.

Another extension of the model which is under development, but was not included in this version is the use of segmentation for the households sector. The payment services monitoring system (PSMS) uses segmented payment statistics to better project and analyse the costs for the different groups in society. These segmentation clusters are being inserted in the model, which will greatly increase the number of agents, but will also increase the compatibility with the PSMS.

7.2. NEW MODULES

Three modules were not used in this model because the calibration and the testing required more disaggregated data which were not available at the time of the development of this version.

The cross-pricing and price differentiation are pivotal parts of the HUPS model and because of the unique characteristics of the Hungarian payment system are necessary for every applied use of the model. In this version the nature of cross pricing and mark-up profits does not differentiate between different types of costs, however, in the last couple of years development showed that some cost shocks – mainly direct taxation – behave differently than others. The direct tax on volumes and values change the rate of the oligopoly mark-up profit and are not cross-directed to other services. A pricing algorithm that differentiate between different types of costs are being developed and calibrated for every future versions of the model to better cope with the observed pricing behaviour of the payment service providers.

Price differentiation means that although every good of the payment sector is a transaction, the pricing does depend on the value of the transaction. In this version, this is modelled by volume and value prices with costs varying with volumes and values. However, in reality the pricing function for the different values are not so simple and a more complicated pricing function algorithm is required. For this to work in this module, we break down the volumes for not just average valued transactions but a full density of different values. The necessary statistics are provided directly from the ACH and RTGS at the transaction level. This module increases the complexity of the HUPS and slows down the evaluation process but makes the results comparable to the PSM system.

The third module that was not activated for this version is a more sophisticated estimated multinomial logistical regression model for the choice of payment methods for every agent. This module requires detailed cross statistics which are inserted from the 1,000-sample survey completed by the MNB and other nationwide surveys for the motives behind payment method choice. The module is currently under calibration and will be inserted in future versions to create more acceptable results for more drastic payment behaviour change scenarios.

There are several other modules and possible extensions for the HUPS model which can easily be connected and inserted to provide more realistic scenarios and plausible results. The high number of these options proves the flexibility of the created theoretical and empirical modelling framework which can support nearly all kinds of behaviours and technological sets behind the payment services supply chains.

8. Conclusions

In our paper we introduced the Hungarian Payment System Model (HUPS), a computable general equilibrium model with detailed payment services which can be used for policy evaluation and forecast.

In recent decades payment habits transformed greatly and a considerable amount of development changed the Hungarian financial infrastructure. To better understand and analyse the impact of payment policy decisions on the entire economy in this dynamic environment, we created a general equilibrium modelling framework and computable general equilibrium model for policy evaluation.

The HUPS model is a large and highly disaggregated computable general equilibrium model with 25 economic agents and nearly 100 payment services which cover most of the payment system supply chain in Hungary. It contains 4 times 7 types of costs for each payment service, varying degree of economies of scale, oligopoly and cross-product pricing and agent behaviour adjustments to payment method costs. In our model, the payment sector is an integrated part of the economy as every actor has to make payment decisions related to its activities.

The scale and size of the model makes it applicable to policy evaluation and can answer questions such as whether a planned policy change has overall positive or negative effect or which agents bear costs and enjoy benefits. Despite its size, the HUPS can still be solved in an acceptable time using its unique solution mechanism. Building a general equilibrium model has the advantages of better modelling the different behaviours of the agents and calculating the very complex interrelations connecting the entire economy through the payment system. The new equilibrium for the different scenarios provides detailed information for the effects of the policy decisions and shows the mechanism in which it is carried out.

The nature of the HUPS model enables us to model extremely complex technological functions for the costs of payment execution, non-linear and non-competitive pricing and a huge number of agents and activities. Its structure provides us with the flexibility to easily integrate new modules, branches of the economy and payment services or inner activities related to their production.

Using the results of our model calibration, we first showed that payment systems account for a significant share of the economy. By following the theoretical assumption of the commonly used macroeconomic models that the execution of payments is costless, our results indicate a 1.15% increase in the level of GDP. This means that these costs are not negligible.

To demonstrate the capabilities of the model, we calculated the impact of two scenarios. We first calculated the effect of the projected change in payment habits for 2020. Using a VAR model for forecasts of the main trends of household and corporate payment habits we evaluated the effect it will have on pricing and profitability of the different payment methods. Our results show that the trend does move towards a more effective payment system, but at a slow rate. Changes in consumer payment habits, mainly card usage and electronic credit transfers result in an increase in the level of GDP. But as it is the case in the current situation, the cost of accepting electronic payments would generally not be less than those of accepting cash payments.

In the second scenario, we calculated the turning point where payment card acceptance generally becomes cheaper for merchants compared to cash acceptance. Based on the results of the model, the already impressive 19% yearly growth rate of the number of card transactions projected from current trends would have to be increased up to 30% to reach that goal. This would require an additional 700 million cash transactions transformed into card payments by 2020, which amounts to 15% of the total number of households' payment transactions.

The HUPS model was developed, calibrated and tested for the Hungarian economy, but the main structure of the model can be applied to any economy because of the significant similarities of the payment systems anywhere in the world. The flexibility of the model enables us to insert any special characteristics of a different economy to better model the unique aspects of the modelled country. However, the implementation of the HUPS model requires a wide range of studies concerning the payment system, most notably a detailed cost of payments study, and a considerable amount of statistical data to support it.

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Appendix

Use of parameter and variable denotations

Index	Capital form	Content
i,j	I,J	branches of economy/number of branches
m	M	payment activities/services, number of activities
psp		payment service provider
	S, D	supply or demand
empty or v		volume and value
f,v		fix or variable cost

In formulas	Short description	Number of parameters in the model
π_i^p	profit	25
p_i	price	15
Y_i	yield	15
W	wage	1
r	rate/return	1+25
L_i^D	labour demand	25
L_i^{Dy}	labour demand in real production	15
L_i^{Dyf}	labour demand in real production fix part	15
L_i^{Dyv}	labour demand in real production variable part	15
L_{mi}^{Dp}	labour demand in payment method production	25
L_{mi}^{Dpf}	labour demand in payment method production fix part	25
L_{mi}^{Dpv}	labour demand in payment method production variable part	25
K_i^D	capital demand	25
K_i^{Dy}	capital demand in real production	15
K_i^{Dyf}	capital demand in real production fix part	15
K_i^{Dyv}	capital demand in real production variable part	15
K_{mi}^{Dp}	capital demand in payment method production	25
K_{mi}^{Dpf}	capital demand in payment method production fix part	25
K_{mi}^{Dpv}	capital demand in payment method production variable part	25
a_i^j	intermediate consumption coefficient in real production	225
a_{mi}^j	intermediate consumption coefficient in payment production	2730
X_i^j	intermediate consumption	375

In formulas	Short description	Number of parameters in the model
X_i^{yj}	intermediate consumption in real production	225
X_{mi}^{pj}	intermediate consumption in payment production	375
M_i	import	25
M_i^y	import in real production	15
M_{im}^p	import in payment production	25
am_i	import coefficient in real production	25
am_{mi}	import coefficient in payment production	4550
p_m	import price	1
AL_i^y	CES parameter for labour in real production	15
AK_i^y	CES parameter for capital in real production	15
σ_i	CES elasticity parameter in real production	15
PMI_{mi}	payment method inner production volume	4550
PS_{mi}^D	payment service outside source volume	750
f_Y^{im}	volume-based payment service share of real sales	1215
f_{xj}^{im}	payment service share of intermediate consumption	2025
f_L^{im}	payment service share of wage payments	2025
f_K^{im}	payment service share of capital return payments	2025
f_M^{im}	payment service share of import payments	2025
θ_Y^{im}	reciprocal of average sales value	2025
θ_{Xj}^{im}	reciprocal of average intermediate consumption payments value	2025
θ_L^{im}	reciprocal of average wage payments value	2025
θ_K^{im}	reciprocal of average capital return payments value	2025
θ_M^{im}	reciprocal of average import payments value	2025
$PSFIX^{im}$	payment service fix volume part	2025
PS_{mi}^{Dv}	payment service outside source value	2025
$PSFIX_v^{im}$	payment service fix value part	2025
φ_m	payment service fee on volume	80
φ_m^v	payment service fee on value	80
NTX_i	net taxes	25
VAT	value added tax	1
TXK	tax rate on capital income	25
TXL	tax rate on labour income	25
TXY	tax rate on revenues	25+180
OTX_i	other taxes	25

In formulas	Short description	Number of parameters in the model
w_i^T or λ_i^1	total labour cost	22
r_i^T or λ_i^2	total capital cost	22
p_{mi}^T or λ_i^3	total import cost	25
λ_i^4	payment methods volume-based total shadow cost	2025
λ_i^5	payment methods value-based total shadow cost	2025
λ_i^6	shadow cost of cash	not included
λ_i^7	shadow cost of electronic money	not included
λ_i^8	shadow cost of tax payments	25

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