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Interaction of Externalities in the Payment Sector and of Externalities in the Rest of the Economy

Abstract: The paper develops a model to show the importance of interaction effects between externalities inside and outside of the payment sector. These interaction effects may easily be more important than those externalities so far examined in the academic literature.

1. Introduction

There is by now a substantial literature on two-sided markets, on network externalities, and in particular also on externalities of payment platforms. This literature – as far as I can see – works with partial equilibrium models. Thus, for example, the papers on externalities in the payment sector, implicitly assume that the price signals underlying the costs and benefits of any payment platform are correct representations of the social (opportunity-) costs and benefits of the goods produced and consumed in the rest of the economy. This implicit assumption may be all right as a reasonable approximation of reality as long as the use of payment modes does not vary strongly between sectors of the rest of the economy. But this last condition does not hold in the real world.

Indeed, preference for one means of payment over another depends on the occasion of payment. Thus, the frequency of use of payment platforms depends on the economic sector in which the payments take place. Groceries tend to be paid by cash or card; monthly rentals for the flat tend to be paid by direct transfer or cheque. Travel related expenses tend to be paid by credit card etc. If payment system A is preferred in sector I and payment system B is preferred in sector II then the well known network externalities in payment platforms imply that payment system A is used "too much" in sector II and "too little" in sector I, whereas payment system B is used "too much" in sector I and is used "too little" in sector II. The "too much" and the "too little" is in comparison with a hypothetical economy in which only one of the sectors exists and thus the use of the two payment systems can be geared to the payment preferences of that sector. If the government were to try to optimize the use of the two payment systems it would then have to take into account that changes in the mix of the two payment systems have different cost effects on the two sectors I and II. By encouraging the use of payment system B the government raises costs (including convenience costs of paying customers) in sector I and reduces costs in sector II, thereby inducing demand shifts from sector I to sector II.

To the extent that different sectors in the rest of the economy exhibit different degrees of externalities we then find an interaction between the payment related externalities and the externalities in the rest of the economy. If, for example, sector I does not exhibit strong externalities and sector II is characterised by strong network externalities, or, as Alfred Marshall would have said, strong external economies of scale, then in a competitive general equilibrium output prices of sector I represent marginal costs of production, whereas output prices in sector II are much above the social marginal cost of production. Thus, by encouraging the use of payment system B, and thereby reducing the relative costs of sector II, the government brings the private costs in the two sectors more in line with social costs of the two sectors, thereby enhancing welfare.

For simplicity of exposition I concentrate in the following on just two payment platforms, which I call "cash" and "credit cards". They stand "pars pro toto" for the world of payment platforms. Also for simplicity I divide the economy into just two sectors, which I call the "local business sector" and the "travel sector". The travel sector may comprise travel in the narrower sense of the word, plus hotels, restaurants, etc., and in addition purchases over the internet and similar activities. The local business sector is the rest of the economy and in particular any business with customers who live nearby.

We observe that the cost structure of the two sectors is likely to be different. The "travel sector" is characterized by what Alfred Marshall used to call "external economies of scale". In the local business sector these "external economies of scale" are the exception rather than the rule. I now describe these "external economies of scale", using the airline industry as an example. Here we observe a rapid growth of productivity. This rapid growth of productivity can be partly explained by the growth of the industry itself. This will be explained now by Marshallian external economies of scale, which strongly overlap with what nowadays has been called "network externalities", but which basically already have been observed by Alfred Marshall a century ago, albeit with a different terminology.

The large majority of people cannot afford private planes, which would transport them directly from wherever they are to their destination. But today most people in Europe can afford an airline ticket. The reason for the substantial cost difference between the use of private airplanes and the use of airline flights are the economies of scale of larger airplanes. The flight of a one hundred passenger aircraft from point A to Point B is not nearly a hundred times more expensive then the flight of a private aircraft on the same route. But equally important as these cost savings due to scale on already highly frequented routes are the benefits of higher volume to be obtained for less frequented routes. In particular, rising general demand allows the commercially viable introduction of new routes, so that air travel becomes available, where it was not available before. And the frequency of traffic can be increased as demand rises. This creates a benefit of higher convenience (greater choice) for customers. A weekly connection is transformed into a bi-weekly connection; a connection four times a week is transformed into a daily connection. A daily connection is transformed into a connection with several departures a day.

Thus, as demand rises increased productivity (including increased customer convenience) leads to lower costs and then lower prices. Rising demand overcomes more and more scale barriers so that new services become commercially viable. Rising demand leads to higher density and convenience and thereby also to lower effective travel time. These advantages to the customer due to higher demand lead themselves to increased demand. Thereby the growth of demand is self- reinforcing. It is a positive feedback loop or a virtuous circle.

An analysis similar to this one has been developed more than three decades ago by Herbert Mohring in the context of public bus service[1]. The benefit of increased demand for all passengers due to the system economies of scale as described above are therefore sometimes called the Mohring effect. The Mohring effect of course implies that cost covering prices must be above the system marginal cost. The system marginal cost is below the system average cost.

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[1] Herbert Mohring, Optimisation and Scale Economies in Urban Bus Transportation, American Economic Review 1972

In present day terminology we talk about network externalities. So the travel sector is full of network externalities. Similarly internet related business exhibits strong network externalities. They have been the cause of the explosive growth of the internet in the nineties and still today. We also include internet based business in the "travel sector".

2. A Two Sector Model of the Economy with two Payment Platforms

For simplicity of the argument I assume that there are no network externalities in the other sector of the economy, which I called the "local business sector". I am aware that this is a rather stylised description of the economy; but I believe agreement can be achieved that the "travel sector" exhibits substantially higher Marshallian external economies of scale (or network externalities) than does the "local business sector". So we can be confident that the argument developed below would also carry over to a model with a more accurate description of network externalities in the real world.

Let x_1 be the real output of the local business sector, let x_2 be the (convenience adjusted) real output of the travel sector. Let L be the total availability of the factor of production used to produce the outputs of the two sectors and of the two payment platforms. We call it "labour". Let L_1 be the labour input into the first sector. We assume the following (inverted) production function

$$L_1 = \lambda_1 x_1$$

Here λ_1 is an input coefficient, which does not depend on the size of the sector. This implies constant returns to scale with respect to sector output. But λ_1 does depend on the mix of payment platforms used in this sector. For the "travel sector" we assume an inverted production function with Marshallian external economies of scale.

$$L_2 = \lambda_2 x_2^{1-\gamma} \text{ with } 0 < \gamma < 1$$

λ_2 does not depend on the size of the sector, but does depend on the mix of payment platforms used in this sector. γ is a constant parameter, which represents the external economies of scale. Output in the "travel sector" must be interpreted as "quality adjusted". Thus, for example, in the aircraft transport a higher density of connections, which reduces effective travel time of passengers, counts as higher output - on top of the higher quantity of passenger kilometres generally coming with higher traffic density. (Alternatively we could have modelled the external economies of scale by assuming that demand for the sector 2 output also depends on the quantity of sector 2 output).

Concerning money values we normalise the unit of account so as to make the "wage" for the production factor "labour" to be unity. Assuming that both sectors sell their product at prices which cover average cost we get

$$p_1 = \lambda_1$$

for the price p_1 of the first sector output. The price p_2 of the "travel sector" then is

$$p_2 = \lambda_2 x_2^{-\gamma}$$

To keep the presentation as simple as possible I assume that prices of the two payment platforms are given and correspond to their resource use per unit of output. By the "price" of the payment platform I mean its average total service charge (=average cardholder charge plus average merchant service charge). Let λ_3 be the price of payment platform 1 ("cash"). Let λ_4 be the price of payment platform 2 ("credit cards"). We then assume that λ_3 and λ_4 are given constants and that they also represent the resource costs of the two payment platforms. We thus implicitly assume constant returns to scale in the payment industry. Nevertheless, as we will see, there are network externalities within payment platforms. The assumption of constant returns to scale in payment platforms is not really needed, but it makes the presentation simpler.

Let s be the share of the second payment platform in the sum of all payments, each payment being weighted by the size of the payment. The resource cost of the payment industry then is

$$L_3 + L_4 = ((1-s)\lambda_3 + s\lambda_4)(L_1 + L_2)$$

To keep the further description of the model as simple as possible I make the assumption that $\lambda_4 = \lambda_3$, i.e. that the resource cost of the two payment platforms is the same. But I want to emphasise that this assumption is not needed for the general argument. Only the proof is slightly more complicated if the resource costs of the payment platform are not the same.

There is then a "resource budget equation" for exogenously given L

$$L_1 + L_2 + L_3 + L_4 = L$$

Before going into the details of the efficiency effects of payment platforms I introduce the demand side of the two sectors of the economy. I assume that the utility function of customers is logarithmic (or, with a different name, "Cobb-Douglas"). We can write the utility function

$$U = x_1^{1-\alpha} x_2^{\alpha}$$

Written in this form utility also can be understood as "real national income": it exhibits "constant returns to scale" with respect to the two goods providing utility. This particular utility function has the advantage of a very simple demand function for the two sector products 1 and 2. Indeed, as is well known from the literature, we have

$$\frac{p_1 x_1}{p_2 x_2} = \frac{1-\alpha}{\alpha}$$

The value shares of the two sectors in total demand for both products are a constant and do not depend on the prices: a one percent rise in the price of one product with total demand remaining the same reduces demand for that product by one percent. In this set-up the parameter α then also represents the share of the "travel sector" in total national product.

Demand for the two payment platforms can be modelled in different ways. We could introduce preferences for the payment platforms. But these "preferences" are derived from other factors. Essentially, depending on the particular payment situation, one of the two payment platforms may be superior to the other in terms of costs and convenience. Here I map these characteristics of the two payment platforms into a cost function for the provision of the two goods of the economy. The productivity of a sector depends on the payment platform mix being used in the sector. We can expect that an exclusive use of only one payment platform in a sector does not maximise its productivity. A certain mix of payment platforms can be characterized by the share s_i of credit card use in this sector. The productivity maximum will be achieved at a value of s_i, which is above zero and below unity. The simplest function to obtain a (cost) minimum between zero and one (for the share s_i) is a quadratic function. This then leads to the following equations for the two sectors

$$\lambda_i = k_i \left(1 - \frac{1-\beta_i}{r_i}\left(2 s_i - \frac{1}{r_i} s_i^{\,2}\right)\right) \text{ for } i = 1,2$$

Here k_1 and k_2 are constants which we can choose at will without loss of generality: we are free to choose the unit in which to measure the output of the two sectors and thus to choose k_1 and k_2. We set $k_1 = 1$. We will determine the value of k_2 later. The economic meaning of the four parameters $\beta_1, \beta_2, r_1, r_2$ is the following. r_i is the value of s_i at which λ_i obtains its minimum, i.e. at which productivity is maximised. β_i is the cost level at this minimum as a proportion of the cost level which would obtain at $s_i = 0$. All four parameters are given exogenously and have values between zero and one. We assume $r_2 > r_1$.

How are the values of s_1 and of s_2 determined? If the government were free to set these two values independently and if the resource costs λ_3 and λ_4 of the payment platforms are the same, it is easy to see that s_i would be set equal to r_i. But there are network externalities in payment platforms; and thus the two shares of credit cards in the two sectors have an influence on each other. The higher the share in one sector the higher will be the share in the other sector: a person, who owns a credit card is likely to use it in both sectors. A person, who does not own a credit card uses cash in both sectors. A merchant who serves both, local customers as well travelling customers, either accepts credit cards or does not accept credit cards. If he does not accept credit cards even his travelling customers pay cash. If he does accept credit cards even some of his local customers pay by credit card. So the share in each sector will rise as the proportion of people owning a credit card rises and as the proportion of merchants accepting credit cards rises. The way I model this interdependence is the following: I assume

$$s_1 = a + \frac{1}{2}\frac{\alpha}{1-\alpha}s_2$$

$$s_2 = \hat{a} + \frac{1}{2}\frac{1-\alpha}{\alpha}s_1$$

Moreover I assume

$$\hat{a} = a + r_2 - r_1$$

The parameter a is exogenously given, but I assume that it can be influenced by government policy, for example by competition policy. The expression for $\hat{a}$ reflects the idea that the intensity of use of a payment platform in a particular sector is influenced by the cost structure in this sector. Thus, if the cost minimising share of credit cards is substantially larger in the travel sector than in the local business sector then it is the case that credit cards will be used more frequently in the travel sector than in the domestic sector. The parameter α is the parameter already used in the demand function for the services of the two sectors and thus represents the share of the travel sector in total national output.

Given that we know a we then can compute the values of the two credit card shares. We first compute the overall share s. It is

$$s = (1-\alpha)s_1 + \alpha s_2 = (1-\alpha)a + \alpha(a + r_2 - r_1) + \frac{1}{2}s = 2(a + \alpha(r_2 - r_1))$$

and then

$$(1-\alpha)s_1 = \frac{4}{3}\left[(1-\alpha)a + \frac{1}{2}\alpha\hat{a}\right]$$

$$\alpha s_2 = \frac{4}{3}\left[\frac{1}{2}(1-\alpha)a + \alpha\hat{a}\right]$$

Note that we have modelled demand for the two payment platforms without introducing their prices. This is possible because their prices λ_3 and λ_4 reflect their exogenously given resource costs and because we have assumed their prices to be the same. We thus can ignore the answer to the question: how would the use of the payment platforms change, if their prices would change? As I said before, the analysis of the model does not depend on this simplifying assumption. It is made to simplify the exposition of the model.

Note also that both, s_1 and s_2, are increasing functions of a.

3. The Laisser Faire Equilibrium as a Reference Point

I have now established the model. The logic of it is the following. A certain amount of labour L is available and will be distributed among the two sectors and the two payment platforms by the following procedure. Government sets the value of a. Thereby the value of $\hat{a}$ is established. These values then lead to the values of s_1 and s_2. If there are no external economies of scale ($\gamma = 0$) the productivity in both sectors is determined in a straightforward manner. With the presence of external economies of scale ($\gamma > 0$) productivity and demand are determined simultaneously in a simple system of equations. The end result is a certain level of welfare as a function of the two sector output levels. The government might aim at setting a so as to maximise welfare.

We are mainly interested in the interdependence between the network externalities of the payment platforms and the Marshallian external economies of scale in the "travel" sector, i.e. in sector 2. In order to isolate the effect of the latter on the optimal policy concerning payment platforms I start with the case $\gamma = 0$, i.e. the case that there are no external economies of scale in the travel sector. So our first thought experiment will provide us with a reference scenario which then serves as a point of comparison. Let us then assume that we have found the optimal value of a which maximizes welfare in the absence of external economies of scale in the travel sector. We designate all equilibrium values corresponding to this welfare maximising a-value by a bar. These values then are

$$\overline{a}, \overline{s}_1, \overline{s}_2, \overline{s}, \overline{\lambda}_1, \overline{\lambda}_2, \overline{p}_1, \overline{p}_2, \overline{x}_1, \overline{x}_2, \overline{L}_1, \overline{L}_2, \overline{L}_3, \overline{L}_4, \overline{U} .$$

For further reference we just need one characteristic of the welfare maximising levels of the credit card shares. We first note that nominal income in this economy is just equal to $L - L_3 - L_4$. By the assumption that the unit resource cost of the two payment platforms is the same the expression $L - L_3 - L_4$ is a constant. Welfare then can be expressed by way of the indirect utility function

$$V = (1-\alpha)^{1-\alpha} \alpha^{\alpha} \frac{L - L_3 - L_4}{p_1^{1-\alpha} p_2^{\alpha}} = U$$

Here the prices p_1 and p_2 are equal to the unit cost in the sectors; hence

$$p_i = \lambda_i$$

We then can derive the inequalities

$$\overline{s}_1 > r_1 \text{ and } \overline{s}_2 < r_2$$

<u>Proof:</u> if $s_1 < r_1$ then by the formulae for the two shares we also have $s_2 < r_2$. But then a small rise in a and hence in s_1 as well as in s_2 would reduce p_1 and would reduce p_2, and thus

would raise welfare. Thus $\bar{s}_1 \geq r_1$. If $s_1 = r_1$ then by the formulae for the two shares we still have $s_2 < r_2$. But then by differentiation we obtain

$$\frac{dp_1}{da} = 0 \text{ and } \frac{dp_2}{da} < 0 \text{, hence } \frac{dV}{da} > 0$$

This then shows $\bar{s}_1 > r_1$. Similarly we show $\bar{s}_2 < r_2$. This completes the proof.

In this reference scenario there are no economies of scale. Thus, in principle it is possible that a competitive economy leads to the welfare maximum of the reference scenario. Assume that the government can influence the parameter a by an appropriate competition policy and without government subsidies for payment systems and without taxes on payment systems so as to achieve the value $\bar{a}$. We then call this reference scenario the laisser faire equilibrium. Absent external economies of scale in the travel sector it is welfare maximising across possible values of the parameter a.

4. Incremental Use of Credit Cards Generates Benefits From External Economies in the "Travel Sector"

Having established this reference point, I now introduce Marshallian external economies of scale in sector 2, the "travel" sector. Thus, I assume $\gamma > 0$. Let us then assume a market equilibrium with the value $a = \bar{a}$. In other words, the government has set the parameter a so as to maximise welfare, if γ were zero. The value $\bar{a}$ corresponds to the laisser faire market equilibrium. This, of course, is no longer the welfare maximizing value of a, because γ is not zero. We now choose the parameter k_2 to be

$$k_2 = \bar{x}_2^{\gamma}$$

From this follows the equation

$$\lambda_2 = \bar{x}_2^{\,\gamma}(1 - \frac{1-\beta_2}{r_2}(2s_2 - \frac{1}{r_2}s_2^{\,2}))$$

and therefore for the price

$$p_2 = \lambda_2 x_2^{\,-\gamma} = (1 - \frac{1-\beta_2}{r_2}(2s_2 - \frac{1}{r_2}s_2^{\,2}))(\frac{x_2}{\bar{x}_2})^{-\gamma}$$

The price in the travel sector then does not only depend on the share of credit cards in the sector, but also on the output level of the sector.

We now can discuss externalities of credit cards induced by Marshallian external economies of scale in the travel sector. Assume – realistically – that credit card use is more intensive in the travel sector than in the local business sector. In our model this is the consequence of the inequality $r_2 > r_1$: the cost minimising level of credit card use is higher in the travel sector than in the local business sector. Due to the external economies of scale in the travel sector we could increase welfare beyond the level of the laisser faire market equilibrium $\overline{U}$, if we had a way to shift some demand from the local business sector to the travel sector: for, the social marginal cost of production is at the market price in the local business sector and is below the market price in the travel sector. One way to accomplish this is for the government to encourage the use of credit cards beyond the equilibrium level obtained by the choice of the parameter $\bar{a}$, that is beyond the laisser faire level. By a more intensive use of credit cards the costs decline in the travel sector - s_2 comes closer to r_2 - and they rise in the local business sector - s_1 moves away from r_1, thereby a shift in demand towards the travel sector is accomplished. This is the basic idea of this chapter.

5. A Numerical Example

How important is this externality in quantitative terms? At this moment nobody has reliable empirical data to find out. In the following I describe a numerical exercise which I have done, by giving the different parameters of the model certain numerical values, which I consider not to be completely unrealistic.

Only for the external economies of scale parameter γ have I investigated three alternative values. All other parameters have a single numerical value. The following table provides these values:

Description	Symbol	Value
External economies of scale in the travel sector	γ	0.25 alternatively 0.333 alternatively 0.5
Income share of travel sector	α	0.3
Cost minimising share of Credit Cards in the local business sector	r_1	0.15
Cost minimising share of Credit Cards in the travel sector	r_2	0.60
Minimum cost relative to "only cash" cost in the local business sector	β_1	0.90
Minimum cost relative to "only cash" cost in the travel sector	β_2	0.80
Resource cost of cash	λ_3	1%
Resource cost of credit cards	λ_4	1%
Cost coefficient in local business sector (cost at "only cash")	k_1	1
Cost coefficient in travel sector (cost at "only cash" and at $x = \bar{x}$) =Unit of quantity of output in the travel sector	k_2	2.76835 if $\gamma = 0.25$ 3.88712 if $\gamma = 0.3333$ 7.66378 if $\gamma = 0.50$
Labour supply	L	166.5466

Some words of explanation for the choice of numbers. The cost coefficient in the travel sector k_2 has been chosen so as to make the computation easy. It has no economic significance, because it simply reflects the choice of unit in which we measure output of that sector. Thus, we measure output in the travel sector in different units for different values of the externality parameter γ. I have then normalized real national output so that it is always equal to U=100 in the reference situation of the laisser faire equilibrium.

The productivity gain due to an optimum mix of payment systems (relative to the extreme situation of "cash only") has been assumed to be 10 % in the local business sector and to be 20 % in the travel sector. This may appear to be large at first glance. But it is not, since we define costs to include convenience effects on the customer side. A payment system like credit cards greatly enhances flexibility and convenience of travelers in locations away from home. They are likely to buy more things when traveling compared to a hypothetical situation, in which they only can pay cash in the local currency. At internet purchases payment by cash is impossible, and thus the benefits of internet purchases would vanish completely at a hypothetical situation without any alternative to cash payments.

In the following table I present the results of the numerical calculation.

Value of γ	Welfare maximising value of parameter a	Welfare maximising Value of s	Welfare U	Welfare gain relative to laisser faire as percentage of total payment costs	Welfare gain as percentage of credit card payment platform revenue
$\gamma = 0$	$\bar{a} = 0.0274$	23.48%	100	0.00%	0.00%
$\gamma = 1/4 = 0.25$	$a^* = 0.0355$	25.10%	100.077	7.70%	30.68%
$\gamma = 1/3 = 0.333$	a^*=0.0395	25.90%	100.183	18.30%	70.66%
$\gamma = 1/2 = o.5$	a^*=0.0515	28.30%	100.876	87.65%	309.72%

Comment on this table of results. The line with $\gamma = 0$ exhibits the laisser faire situation. It also prevails if γ is different from zero, because obviously the market solution ignores the externality effects. In order to achieve the social optimum the government would have to find a way to increase the credit card share from its laisser faire value of 23.48 % by 1.62 percentage points in the case of γ=1/4, by 2.42 percentage points in the case of γ= 1/3 and by 4.82 percentage points in the case $\gamma = ½$. In this latter case the welfare maximising share of credit cards is more than 20 % higher than in the laisser faire equilibrium.

The welfare impact of this change in the share of credit cards naturally is small, if seen as a percentage of real national income. But it is substantial, if seen as a percentage of the size of the payment sector. Indeed, in the case γ = ½ this welfare impact amounts to 87.65 % of resource costs of payment platforms or more than three times the revenue of the credit card payment platform. To put this statement in different words: a 20 % increase in business for the credit card platform above its market equilibrium value would generate a real income boost in the economy 15 times larger than this additional commercial revenue. In the case of $\gamma = 1/3$ the corresponding sentence would read: a 10 % increase in business for the credit card platform would generate a real income boost in the economy seven times larger than this additional commercial revenue. In the case of $\gamma = 1/4$ the corresponding sentence would read: a 7 % increase in business for the credit card platform would generate a real income boost in the economy more than four times larger than this additional commercial revenue.

This exercise in modelling externalities can of course be criticized for its lack of empirical support. Trying to calibrate the parameters of the model by data collection and econometric analysis would require a substantial research effort.

But even if this numerical exercise does not have a solid empirical basis we can ask the question: is an external economies of scale parameter γ of one half completely unrealistic? To obtain some intuition we can put it this way: A parameter value for γ of ½ implies: if the travel sector expands fourfold its average cost is halved, due to external economies of scale. This is not completely unrealistic, if we remember that we do not only talk about passenger costs per person kilometer or freight costs per ton kilometer. We also have to include gains in convenience coming from a higher density of point to point connections etc. For internet related business a parameter estimate of ½ may be too low. For bus services, for the railway system, for passenger air transport it may be realistic. For the road system for cars it might be lower than ½, but still substantial.

A parameter value for γ of 1/3 implies: if the travel sector expands eightfold its average cost is halved, due to external economies of scale; and a parameter value for γ of 1/4 implies: if the travel sector expands sixteen fold its average cost is halved, due to external economies of scale.

6. Conclusion

From a social engineering point of view externalities of payment platforms may be quite important. But the discussion in the literature has concentrated only on a rather narrow set of such externalities. It has ignored interdependencies between network externalities in the payment sector and external economies of scale in the rest of the economy. These interdependencies may generate more important welfare effects than those externalities, which so far have been investigated in the literature.

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