Payment Industry Dynamics: A Two-Sided Market Approach*

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June 10, 2006

Abstract

This paper provides a theory of payment industry dynamics, in which we focus on the monetary nature of payment devices and consider an alternative microfoundation for the two-sided market approach. In a competitive economy, the adoption of an emerging payment method is determined by the distribution of consumer incomes and firm sizes, and the change of consumer income, adoption cost, and card-industry market structure each have important influence on payment pricing and usage dynamics. Our findings suggest that both the increasing concentration of payment card network and the growth of consumer income relative to card service costs may help explain the puzzles surrounding payment card interchange fees.

Keywords: Technology Adoption, Two-sided Market, Asymmetric Pricing

JEL Classification: L10, D40, O30

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*Preliminary draft, please do not quote. We thank Nathan Halmrast for valuable research assistance. The views expressed herein are solely those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of New York, the Federal Reserve Bank of Kansas City or the Federal Reserve System.

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1 Introduction

1.1 Motivation

Payment devices, whether currency, cards, or coin, are distinguished by their monetary character. In retail transactions, a payment device serves to transfer money from a consumer to a merchant to settle the obligation that is part and parcel of purchasing a good or service from the merchant. We model the adoption of a payment device by consumers and merchants in a retail economy in which the agents value payment devices for their monetary purposes.

Consider two payment devices, cash and an electronic payment card, for example. Both convey monetary value, but may differ in their fixed and variable costs of use to different agents. A consumer prefers a particular device if, given that the merchant has adopted the device, it is less costly for the consumer to settle her obligation to the merchant than the alternative. In other words, a consumer's demand for a payment device is an indirect demand; the preferred device increases the consumer's purchasing power relative to the alternative.

A merchant's considerations are different. The merchant has a direct demand for the payment device as an input into her production (conditional on the consumer's use of the particular device). In addition, the merchant is sensitive to the consumers' use of the device, as the preferred device of the consumer increases the consumers' demand for the merchant's product. The merchant, as a result, also has an indirect demand for a particular device, which is dependent on the terms on which the consumer is offered the device, as is made clear by Farrell (2006).

By focusing on the monetary character of payment devices, we derive a natural asymmetry in the optimization problems of individual consumer and merchant. For the consumer, only the own-price of the payment device enters into her optimization decision. For the merchant, however, both its own-price and the price facing the consumer enter into its decision. Moreover, the heterogeneity of consumer income and firm size create further asymmetry at the aggregate industry level.

This approach to modeling the adoption of payment devices results in a model of a two-sided market. However, it stands in contrast to much of the literature regarding payment devices, with the notable exceptions of Farrell (2006) and Rochet and Tirole (2006). In the more standard approach to modeling payment device markets in the two-sided market literature, as in Baxter (1983), Rochet and Tirole (2000), Schmalensee (2002), and Wright (2003), consumers and merchants derive benefits b_c and b_m, respectively, from their use of a particular payment device. Under conditions that lead to two-sided markets (Rochet and Tirole (1999)) interchange fees then play a role in balancing the demands on the two sides of the markets for some objective, either to maximize transaction volume (welfare) or to maximize the profits of the provider of the payment device. This modeling technique has the merchants and consumers in essentially symmetric positions, both having direct demands for the payment device.

In the now standard approach, the consumer's benefit from the use of the card, b_c, is referred to as the convenience benefit from the payment device. Although these models are partial equilibrium models (as is the one we present) they largely overlook the monetary nature of the payment device. These models are only partially applicable to payment devices, and only so when the payment device, such as a payment card, offers some direct benefit (utility) to the consumer in addition to the ability to make monetary transfers. In contrast, the model we explore ignores any nonmonetary characteristic of the payment device, and examines adoption and use in the environment in which the monetary characteristics of payment devices are their only raison d'être.

There are several benefits to focusing on the monetary characteristics of payment devices. Most important, this approach yields clear empirically relevant hypotheses. For consumers, consider the introduction of a payment device with a high fixed but low variable cost of use. More affluent consumers, with higher levels of consumption

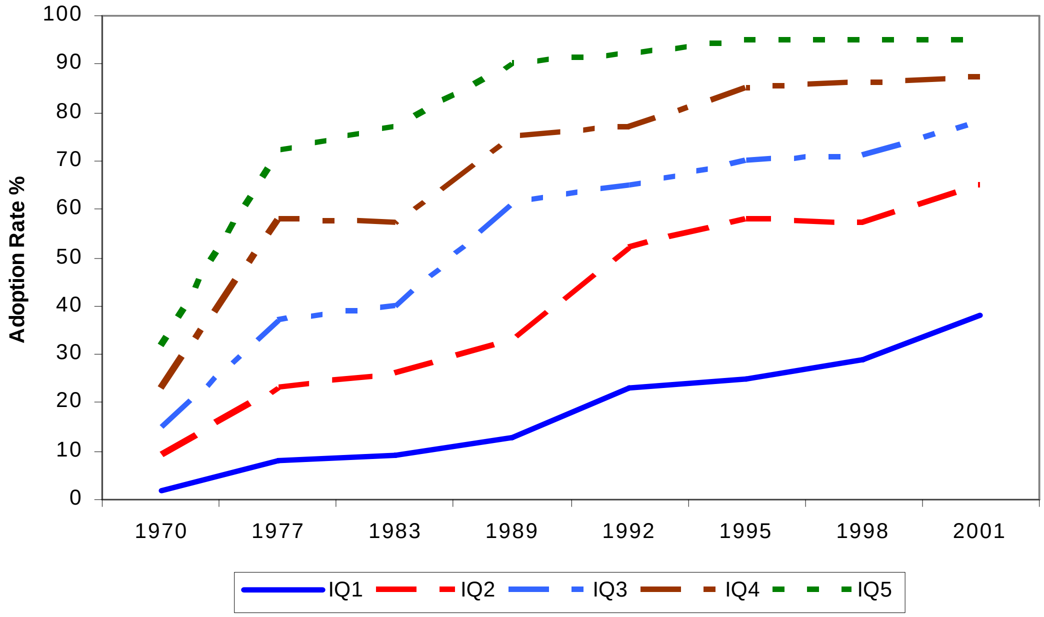

Figure 1: Household Credit Card Adoption by Income Quintile

and purchases, will choose to adopt the device prior to less affluent consumers. For merchants, facing a similar adoption decision, the larger merchants, or those who sell a higher valued good, will adopt the device earlier than other merchants. These predictions are consistent with empirical evidence (Figure 1 and 2)[1]. In contrast, the literature that overlooks the monetary nature of payment devices does not yield such straightforward empirical conclusions without additional assumptions about how the specific convenience benefits are distributed among consumers and merchants.

Our model's asymmetry between the consumer and merchant, consistent with Farrell (2006), yields predictions on the interchange fee which are different from the standard prediction of Rochet and Tirole (2000) and subsequent literature. The standard approach focuses its explanations of behavior and pricing on a distribution of preferences among a heterogeneous population of consumers. Our approach focuses on a distribution of enowments, specifically income, among a heterogeneous distri-

[1]Data source: Evans and Schmalensee (2005), *Paying with Plastic*, 2nd edition.

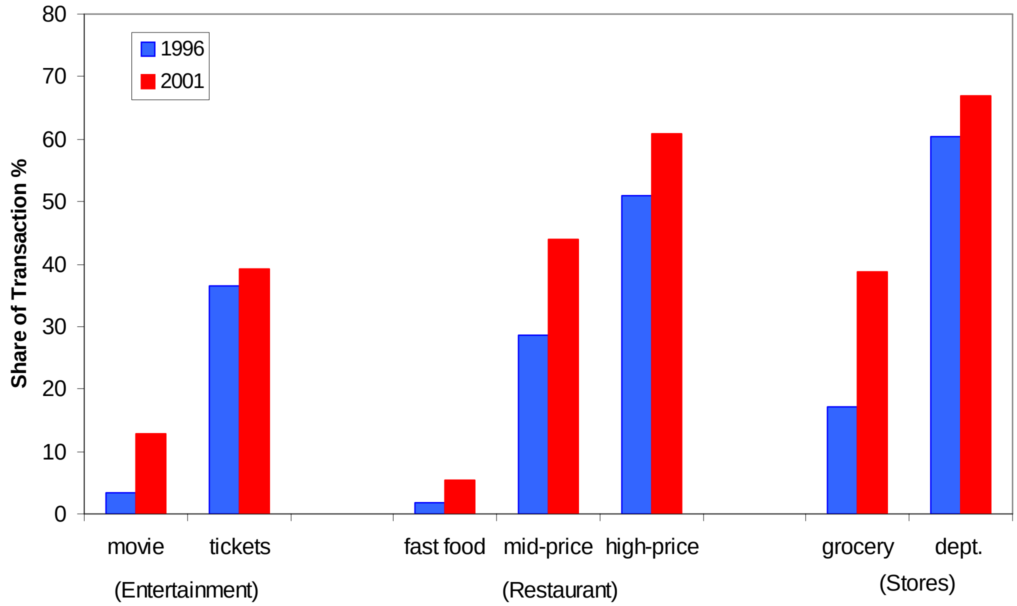

Figure 2: Payment Card Share of Transaction Volume by Merchant Type

bution of consumers. The standard approach focuses on strategic rivalry among merchants in a Hotelling model, or rivalry among card issuers to generate external effects among the agents; we focus on the size distribution of firms as the crucial empirical issue in a market in which price coherence provides the motive for the two-sidedness of the market.

By focusing on the moneyness of payment devices, we might be criticized for overlooking nonmonetary benefits consumers or merchants might derive from their use. We offer three defences. First, the monetary nature of payment devices is arguably their primary purpose. Second, many convenience benefits of payment devices (e.g. protect from theft or time saving), are closely related with the income and spending of the consumer, and are therefore better captured by our model through the variable cost of use of the payment device. Third, it may be appropriate to model both the monetary and other, direct, benefits of a payment device. But we believe that only by first investigating the adoption pattern of a monetary payment device can we understand the circumstances under which sellers of payment devices will choose to employ a strategy of tying a direct benefit (not related to the income of the consumer) to the use of the device, and determining on which side of the market those benefits might be offered. By overlooking the monetary nature of payment devices, one is apt to misunderstand the basic asymmetry between the economic roles of the consumer and the merchant.

1.2 New Approach

We model the consumers as having generalized Cobb-Douglas preferences across a range of goods. They take prices as given. Each consumer is endowed with income, which is distributed across the population of consumers according to known cumulative distribution function. The merchant side of our model is quite stylized. Each merchant competes in a contestable market for the single good the merchant sells, and prices are set at the zero profit level. The size of an individual merchant is hence tied to the consumers' demand.

Consumers and merchants are both presented with the option to adopt a new payment device that offers a lower variable cost of use, but a higher fixed cost relative to the pre-existing alternative. They each make their optimal adoption decision taking the other's choice as given. The model yields a two-sided market, given the heterogeity of consumer incomes and merchant sizes and under price coherence of merchants that accept both payment devices.[2] We then examine the adoption decisions under various market structures for the provision of the payment device, including a competitive (zero-profit) market structure in which no interchange fees are feasible, a competitive (or zero-profit) structure in which interchange fees are feasible, a monopoly structure,

[2] We rule out merchants that specialize in card-only transactions (see Wright (2003) for a discussion) by assuming that the economy offers a facility, like physical stores, within which merchants sell their goods. The costs of the facility are sunk. A card-only merchant would be required to invest in a costly store to conduct business, which is too expensive to be feasible.

and the solution that would be determined by a social planner. Our analyses show that consumer income, adoption cost, and market structure each play important roles in determining the pricing and usage of payment devices. Moreover, we find no market structure yields the planner's solution, in contrast with some previous literature, including Schmalensee (2002).

Our model can be readily applied to the payment card industry. It suggests that both the increasing concentration of payment card network and the growth of consumer incomes relative to card service costs may help explain the puzzles surrounding interchange fees pointed out in Hayashi (2005) and Weiner and Wright (2005). Here, it is worth emphasizing the differences between our model and others. The existing studies on payment card market typically assume imperfect competition among merchants, e.g. Hotelling competition. Those models allow the merchants to behave strategically and consider the business stealing motive for adopting payment cards, but can not easily keep track of industry dynamics. In contrast, our model assumes competitive merchants and highlights the positive and normative consequences of market structure, income growth, and adoption costs in a nonstrategic (merchant) environment. The richness of the strategic approach is sacrificed in favor of a focus on the interplay between individual firm and consumer decision-making and aggregate industry characteristics. As a result, our model provides a convenient framework to study evolution of payment card industry both in the short run (illustrating the network "chicken-egg" dynamics) and long-run (illustrating adoption and pricing dynamics due to cost and income changes), and offers some further insights into the related competitive policy issues.

1.3 Road Map

In the next section we lay out our model in greater detail and derive some preliminary results. In section 3 we review numerical analyses of the equilibria of our model, and apply our findings to the interchange fee puzzles of payment cards. In section 4 we offer concluding remarks and suggestions for future research.

2 The Model

Here we present our model to study pricing and adoption of monetary payment devices. We first lay out the environment in which only one payment device, which we refer to as cash, is in use. Later we will consider the introduction of an alternative device, which we refer to as a payment card.

2.1 Pre-card Market Environment

The economy is composed of a continuum of merchants. Each merchant locates in a physical store and sells a distinct product α. The store facility is sunk and each product market is contestable, so merchants always sell at cost:

$$(1-\tau_m)p_\alpha = c_\alpha \Longrightarrow p_\alpha = \frac{c_\alpha}{1-\tau_m}$$

where p_α and c_α are price and cost for good α respectively; τ_m is the cash payment cost to the merchant. The cost of the cash payment includes the handling, storage, and safekeeping costs the merchant expends in accepting cash.

A consumer would like to consume all varieties of products, has generalized Cobb-Douglas utility, and seeks to maximize her utility subject to her income I:

$$U = Max \int_{\underline{\alpha}}^{\overline{\alpha}} \alpha \ln x_\alpha dG(\alpha) \qquad s.t. \qquad \int_{\underline{\alpha}}^{\overline{\alpha}} (1+\tau_c) p_\alpha x_{\alpha,I} dG(\alpha) = I$$

where $\alpha \in [\underline{\alpha}, \overline{\alpha}]$ is the preference parameter distributed with cdf $G(\alpha)$, $x_{\alpha,I}$ is her quantity of demand for good α, τ_c is the cost of a cash payment to the consumer. As with the merchant, the consumer faces costs in handling and transporting cash.

Therefore, the demand and spending of an individual consumer on good α can be determined as

$$x_{\alpha,I} = \frac{\alpha I}{(1+\tau_c)p_\alpha E(\alpha)}; \qquad p_\alpha x_{\alpha,I} = \frac{\alpha I}{(1+\tau_c)E(\alpha)}$$

Across consumers, the income $I \in [\underline{I}, \overline{I}]$ is distributed with cdf function $F(I)$ and mean $E(I)$. Normalize the aggregate measure of consumer to be unity. At equilibrium, market supply equals demand, so the market output and value for product α are as follows:

$$x_\alpha = \frac{\alpha E(I)}{(1+\tau_c) p_\alpha E(\alpha)}; \quad p_\alpha x_\alpha = \frac{\alpha E(I)}{(1+\tau_c) E(\alpha)}$$

2.2 Card Adoption and Market Equilibrium

At time T, a payment innovation, e.g. a card, is introduced. The card service is provided by a card network. It charges merchants and consumers, respectively, a proportional fee f_m and f_c. The costs of providing the card service to merchants and consumers are d_m and d_c, respectively. For merchants and consumers, there is a per-period adoption cost k_m (e.g., a fixed cost of renting card-processing equipment) and k_c (e.g., a fixed cost of maintaining banking account balance or credit score). At equilibrium, large merchants and wealthy consumers have an advantage in adopting the payment card. To see that, let us construct the following equilibrium: given that merchants $\alpha > \alpha_0$ accept the card, consumers of income $I > I_0$ would like to adopt the card, and vice versa.

2.2.1 Consumers' Choice

An individual consumer takes market prices and merchants' card acceptance as given to make her own adoption decision. Given that merchants $\alpha > \alpha_0$ accept the card, she compares the utility of adopting card or not. An adopter who enjoys higher utility from adoption meets the following condition:

$$\begin{aligned} & \int_{\underline{\alpha}}^{\overline{\alpha}} \alpha \ln \frac{\alpha I}{(1+\tau_c) p_\alpha E(\alpha)} dG(\alpha) \\ < \; & \int_{\underline{\alpha}}^{\alpha_0} \alpha \ln \frac{\alpha (I - k_c)}{(1+\tau_c) p_\alpha E(\alpha)} dG(\alpha) + \int_{\alpha_0}^{\overline{\alpha}} \alpha \ln \frac{\alpha (I - k_c)}{(1+f_c) p_\alpha E(\alpha)} dG(\alpha) \end{aligned}$$

which implies that

$$E(\alpha)\ln\frac{I}{(I-k_c)} < E_{\alpha>\alpha_0}(\alpha)\ln\frac{(1+\tau_c)}{(1+f_c)} \tag{1}$$

where $E_{\alpha>\alpha_0}(\alpha) \equiv \int_{\alpha_0}^{\overline{\alpha}} \alpha dG(\alpha)$.

Equation 1 suggests that for any individual consumer to adopt card , we need

$$\tau_c > f_c$$

and the adopters' income has to be over the threshold income I_0

$$I > I_0 = \frac{k_c}{1-(\frac{1+f_c}{1+\tau_c})^{E_{\alpha>\alpha_0}(\alpha)/E(\alpha)}} \tag{2}$$

More intuitively, we may take first-order Taylor expansion of Equation 1 as follows:

$$E(\alpha)\frac{k_c}{(I-k_c)} < E_{\alpha>\alpha_0}(\alpha)\frac{(\tau_c-f_c)}{(1+f_c)}$$

which suggests that for an individual consumer to adopt card, the cost saving of using card has to be worth the adoption cost:

$$\underbrace{(\tau_c-f_c)}_{\text{cost saving}} \quad \underbrace{\frac{(I-k_c)E_{\alpha>\alpha_0}(\alpha)}{E(\alpha)(1+f_c)}}_{\text{card transactions}} \quad > \underbrace{k_c}_{\text{adoption cost}}$$

Notice that only the consumer's own-price of using cards f_c and k_c, enters the consumer's decision to adopt cards, and only as a result of a card offering greater net purchasing power to the consumer, as the card has lower variable costs of use to the consumer, $\tau_c > f_c$.

2.2.2 Merchants' Choice

A merchant takes consumers' card acceptance as given to make her card acceptance decision. In particular, she has to decide whether accepting the card lowers the cost or not.

If she accepts the card, she charges price $p_{\alpha,d}$ and receives the following revenues from card customers and cash customers, respectively:

$$p_{\alpha,d}x_{\alpha,d}^{card} = \frac{\alpha[E_{I>I_0}(I-k_c)]}{E(\alpha)(1+f_c)}; \quad p_{\alpha,d}x_{\alpha,d}^{cash} = \frac{\alpha[E_{I<I_0}(I)]}{E(\alpha)(1+\tau_c)} \tag{3}$$

where $E_{I>I_0}(I) \equiv \int_{I_0}^{\overline{I}} IdF(I)$.

Contestability imposes a zero profit condition, which requires that revenue equals cost

$$(1-f_m)p_{\alpha,d}x_{\alpha,d}^{card} + (1-\tau_m)p_{\alpha,d}x_{\alpha,d}^{cash} = c_\alpha x_{\alpha,d}^{card} + c_\alpha x_{\alpha,d}^{cash} + k_m \tag{4}$$

Therefore, Equation 3 and 4 pin down the price $p_{\alpha,d}$ as follows

$$p_{\alpha,d} = \frac{c_\alpha \frac{\alpha[E_{I>I_0}(I-k_c)]}{(1+f_c)} + c_\alpha \frac{\alpha[E_{I<I_0}(I)]}{(1+\tau_c)}}{(1-f_m)\frac{\alpha[E_{I>I_0}(I-k_c)]}{1+f_c} + (1-\tau_m)\frac{\alpha[E_{I<I_0}(I)]}{1+\tau_c} - k_m E(\alpha)}$$

If she does not accept card, she charges price $p_{\alpha,c}$ to consumers, which has been shown to be

$$p_{\alpha,c} = \frac{c_\alpha}{1-\tau_m} \tag{5}$$

Contestability suggests that a merchant serving both card and cash customers would like to accept card if

$$p_{\alpha,d} < p_{\alpha,c} \Longrightarrow \frac{c_\alpha \frac{\alpha[E_{I>I_0}(I-k_c)]}{(1+f_c)} + c_\alpha \frac{\alpha[E_{I<I_0}(I)]}{(1+\tau_c)}}{(1-f_m)\frac{\alpha[E_{I>I_0}(I-k_c)]}{1+f_c} + (1-\tau_m)\frac{\alpha[E_{I<I_0}(I)]}{1+\tau_c} - k_m E(\alpha)} < \frac{c_\alpha}{1-\tau_m}$$

It implies that a merchant has to be over the threshold size α_0 to accept card

$$\alpha > \alpha_0 = \frac{E(\alpha)k_m(1+f_c)}{[E_{I>I_0}(I-k_c)](\tau_m - f_m)} \tag{6}$$

Equation 6 suggests that for any individual merchant to adopt card, we need

$$\tau_m > f_m$$

and the cost saving of accepting card has to be worth the adoption cost:

$$\underbrace{(\tau_m - f_m)}_{\text{cost saving}} \underbrace{\frac{\alpha[E_{I>I_0}(I-k_c)]}{E(\alpha)(1+f_c)}}_{\text{card transaction}} > \underbrace{k_m}_{\text{adoption cost}}$$

In contrast to the consumer, the merchant's decision to adopt the card innovation involves both the merchant's and consumers' variable and fixed cost of adopting the card. This asymmetry in the consumer's and merchant's decision problem is a key feature of the monetary approach to modeling payment card adoption.

Notice also that some merchants $\alpha < \alpha_0$ may want to accept card and charge $p_{\alpha,d}$ to exclusively serve the card customers. As long as

$$\frac{1+\tau_c}{1+f_c} p_{\alpha,c} > p_{\alpha,d} > p_{\alpha,c}$$

they are able to attract the card customers only. However, this implies some new stores have to be built, as existing stores will accept both types of consumers, card and cash consumers. Assume there is a cost K associated with building a new store where

$$\underbrace{(\tau_c - f_c)}_{\text{cost saving}} \underbrace{\left(\frac{(1-f_m)\alpha_0[E_{I>I_0}(I-k_c)]}{E(\alpha)(1+f_c)} - k_m\right)/(1+\tau_c)}_{\text{alternative cash transaction}} < \underbrace{K}_{\text{store cost}}.$$

It is not worthwhile to build any additional stores to exclusively serve the card users. Hence, this case is ruled out and the market is two-sided as a result of the inability of a merchant to price-discriminate between card and cash purchases.

2.2.3 Market Equilibrium

Equations 2 and 6 pin down the interrelationship between consumers' card adoption and merchants' card adoption. Recall the threshold values:

$$I_0 = \frac{k_c}{1 - (\frac{1+f_c}{1+\tau_c})^{E_{\alpha>\alpha_0}(\alpha)/E(\alpha)}}; \qquad \alpha_0 = \frac{E(\alpha)k_m(1+f_c)}{[E_{I>I_0}(I-k_c)](\tau_m - f_m)} \tag{7}$$

which confirms that higher the merchants' adoption, higher the consumers' adoption, and vice versa. Give this finding, we discuss equilibrium outcomes under four alternative market structures as follows.

(1) Competitive Network without Interchange Fee First, in a competitive card service market where it is not feasible to assess an interchange fee, we have

$$f_m = d_m \quad \text{and} \quad f_c = d_c$$

then the adoption thresholds are

$$I_0 = \frac{k_c}{1 - (\frac{1+d_c}{1+\tau_c})^{E_{\alpha>\alpha_0}(\alpha)/E(\alpha)}}; \qquad \alpha_0 = \frac{E(\alpha)k_m(1+d_c)}{[E_{I>I_0}(I-k_c)](\tau_m - d_m)}$$

The corresponding card transaction volume is

$$\frac{E_{\alpha>\alpha_0}(\alpha)E_{I>I_0}(I-k_c)}{E(\alpha)(1+d_c)}$$

(2) Competitive Network with Interchange Fee If charging an interchange fee is feasible, a competitive card network (e.g. a non-profit bank association) can achieve more card transactions by setting the merchant and consumer fees (the price structure) as follows:

$$\underset{f_c, f_m}{Max} \frac{E_{\alpha>\alpha_0}(\alpha)E_{I>I_0}(I-k_c)}{E(\alpha)(1+f_c)}$$

$$s.t. \;\; \alpha_0 = \frac{E(\alpha)k_m(1+f_c)}{[E_{I>I_0}(I-k_c)](\tau_m - f_m)}$$

$$I_0 = \frac{k_c}{1 - (\frac{1+f_c}{1+\tau_c})^{E_{\alpha>\alpha_0}(\alpha)/E(\alpha)}}$$

$$d_m + d_c = f_c + f_m$$

(3) Monopoly Network A monopoly card network would like to maximize the card revenue instead of transaction volume. It solves the following problem:

$$\underset{f_c,f_m}{Max}\frac{E_{\alpha>\alpha_0}(\alpha)E_{I>I_0}(I-k_c)}{E(\alpha)(1+f_c)}(f_c+f_m-d_m-d_c)$$

$$s.t.\quad \alpha_0=\frac{E(\alpha)k_m(1+f_c)}{[E_{I>I_0}(I-k_c)](\tau_m-f_m)}$$

$$I_0=\frac{k_c}{1-(\frac{1+f_c}{1+\tau_c})^{E_{\alpha>\alpha_0}(\alpha)/E(\alpha)}}$$

(4) Social Planner The social planner would like to maximize the social surplus of using a more efficient payment device, taking into account the adoption costs of consumers and merchants, and subject to the incentive constraints of both:

$$\underset{f_c,f_m}{Max}\frac{E_{\alpha>\alpha_0}(\alpha)E_{I>I_0}(I)}{E(\alpha)(1+\tau_c)}(\tau_c+\tau_m)-\frac{E_{\alpha>\alpha_0}(\alpha)E_{I>I_0}(I-k_c)}{E(\alpha)(1+f_c)}(d_m+d_c)-(1-G(\alpha_0))k_m-(1-F(I_0))k_c$$

$$s.t.\quad \alpha_0=\frac{E(\alpha)k_m(1+f_c)}{[E_{I>I_0}(I-k_c)](\tau_m-f_m)}$$

$$I_0=\frac{k_c}{1-(\frac{1+f_c}{1+\tau_c})^{E_{\alpha>\alpha_0}(\alpha)/E(\alpha)}}$$

Findings The four alternative market structures yield different outcomes. We can clearly see that (1) with an interchange fee, only the sum of the payment card cost d_m+d_c matters; (2) an interchange fee improves the cost allocation and helps achieve higher card adoption and usage for the competitive network; (3) a monopoly card network maximizes the card revenue instead of transaction volume, so it prefers lower card usage than the competitive network; (4) the social planner maximizes the social surplus of using a more efficient payment device. In particular, the cost saving of using card relative to cash, i.e., $(\tau_c + \tau_m)$ relative to $(d_m + d_c)$, and the card adoption costs $(k_c,\ k_m)$ are in the social planner's calculation but not in (any of) the card network's objectives. Therefore, in general, the social optimal outcome is different from the competitive or monopoly market outcome.

3 Numerical Analysis

To better illustrate our findings, we consider an explicit example as follows.

Assume $\alpha \in (0, 1)$ is uniformly distributed with $E(\alpha) = 1/2$, and $I \in [0, \infty)$ is exponentially distributed with $F(I) = 1 - e^{(-\lambda I)}$ and $E(I) = 1/\lambda$. We can rewrite Equation 7:

$$\alpha_0 = \frac{k_m(1 + f_c)}{2e^{(-\lambda I_0)}(\frac{1}{\lambda} + I_0 - k_c)(\tau_m - f_m)} \tag{L1}$$

$$I_0 = \frac{k_c}{1 - (\frac{1+f_c}{1+\tau_c})^{1-\alpha_0^2}} \tag{L2}$$

3.1 Short-run (Transitional) Dynamics

Characterizing Equation L1, we have

$$\alpha_0|_{I_0 \longrightarrow 0} \longrightarrow \frac{k_m(1 + f_c)}{2(\frac{1}{\lambda} - k_c)(\tau_m - f_m)} > 0\ ; \quad \alpha_0|_{I_0 \rightarrow \infty} \longrightarrow \infty$$

$$\frac{d\alpha_0}{dI_0} > 0\ ; \quad \frac{d^2\alpha_0}{dI_0^2} > 0;$$

Characterizing Equation L2, we have

$$I_0|_{\alpha_0 \rightarrow 0} \rightarrow \frac{k_c(1 + \tau_c)}{(\tau_c - f_c)} > 0\ ; \quad \alpha_0|_{I_0 \longrightarrow \infty} \longrightarrow 1$$

$$\frac{d\alpha_0}{dI_0} > 0\ ; \quad \frac{d^2\alpha_0}{dI_0^2} < 0$$

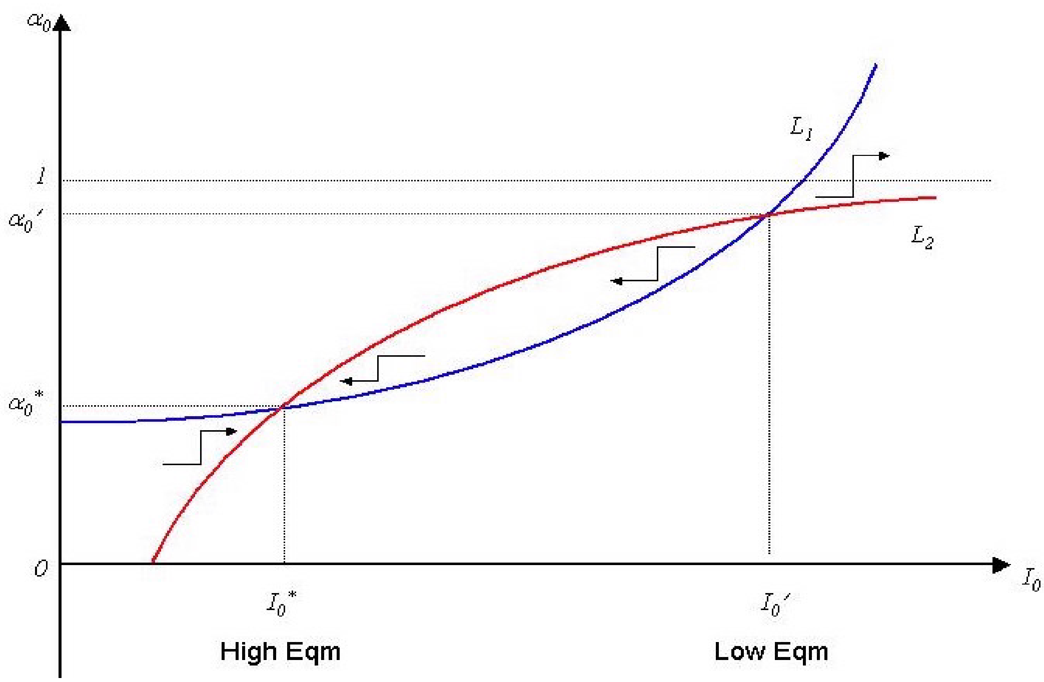

Figure 3: Interaction of Merchants and Consumers in Card Adoption

Figure 3 illustrates the interactions of card adoption between merchants and consumers and the corresponding transitional dynamics. There exist two steady states: a high-adoption equilibrium (I_0^*,α_0^*) and a low-adoption equilibrium ($I_0^{'}$,$\alpha_0^{'}$). The high equilibrium is stable but the low equilibrium is not. As a result, the card network has incentive to push the card adoption to overcome the low equilibrium. Our analysis suggests if the initial card adoption is high enough, the market will achieve the high equilibrium. Otherwise, card adoption may fail, and suffer no adoption.

3.2 Long-run Dynamics

Using the high-adoption equilibrium, we can numerically compare the long-run industry dynamics under four different market structures. For the benchmark simulation, we use the following parameterization: $\tau_m = 0.05$, $\tau_c = 0.05$, $d_c < 0.05$, $d_m < 0.05, k_c = 125$, $k_m = 125$, $\lambda = 0.0001$. Based on that, we plot Figure $4 - 7$

corresponding to each market structure. To study the comparative dynamics, we then adjust the values of k_c, k_m and λ to see the effects of changing consumer income and adoption costs on card pricing and usage (results are shown in the Appendix).

3.2.1 Competitive Card Network without Interchange Fee

If it is not feasible for the competitive card network to set an interchange fee (other than zero), merchants and consumers will face their respective card service costs:

$$f_m = d_m \quad \text{and} \quad f_c = d_c$$

Therefore, the adoption thresholds are

$$I_0 = \frac{k_c}{1 - (\frac{1+d_c}{1+\tau_c})^{1-\alpha_0^2}}; \qquad \alpha_0 = \frac{k_m(1+d_c)}{2e^{(-\lambda I_0)}(\frac{1}{\lambda} + I_0 - k_c)(\tau_m - d_m)}$$

and the corresponding card transaction volume is

$$\frac{e^{(-\lambda I_0)}(\frac{1}{\lambda} + I_0 - k_c)(1-\alpha_0^2)}{(1+d_c)}$$

3.2.2 Competitive Card Network with Interchange Fee

If the competitive card network can set an interchange fee, then only the sum of card service costs $d_m + d_c$ matters. Therefore, the card network achieves better cost allocation and higher card adoption and usage.

$$\underset{f_c, f_m}{Max} \;\; e^{(-\lambda I_0)}(\frac{1}{\lambda} + I_0 - k_c)(\frac{1-\alpha_0^2}{1+f_c})$$

$$s.t. \quad \alpha_0 = \frac{k_m(1+f_c)}{2e^{(-\lambda I_0)}(\frac{1}{\lambda} + I_0 - k_c)(\tau_m - f_m)}$$

$$I_0 = \frac{k_c}{1 - (\frac{1+f_c}{1+\tau_c})^{1-\alpha_0^2}}$$

$$d_m + d_c = f_c + f_m$$

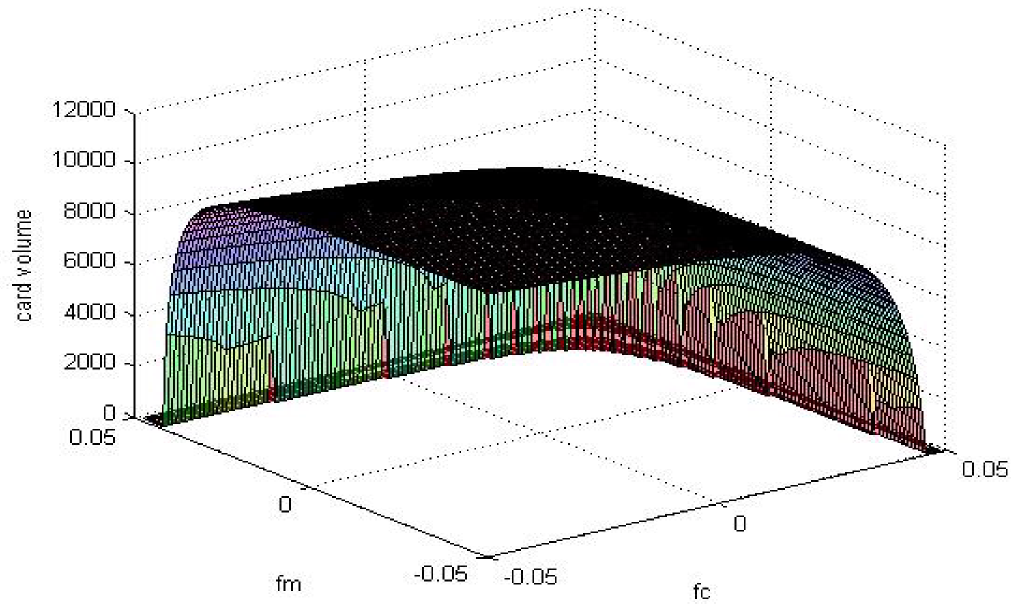

Figure 4: Card Fees and Transaction Volume

Figure 4 shows the card transaction volume corresponding to each card fee schedules (f_c, f_m) (where the interchange fee is implicitly determined as the amount transferred, $|(f_m - d_m)| = |(f_c - d_c)|$). Under a competitive card system without interchange fee, the card usage is a point on the volume surface corresponding to the given cost parameters $f_m = d_m$ and $f_c = d_c$. It is straightforward to see that interchange fee can help the card system to generate more card usage at a given total cost $d_m + d_c$. To illustrate that, we may slice the volume surface in Figure 4 by lines where $f_c + f_m$ is a constant. The resulting curves are shown in Figure 5. Several findings emerge for the competitive (zero-profit) card system:

- For a given total card cost $d_c + d_m$, a unique fee structure (and corresponding interchange fee) f_c and f_m generates the maximum card transaction;
- As the total card cost decreases, the maximum number of card transactions increase;

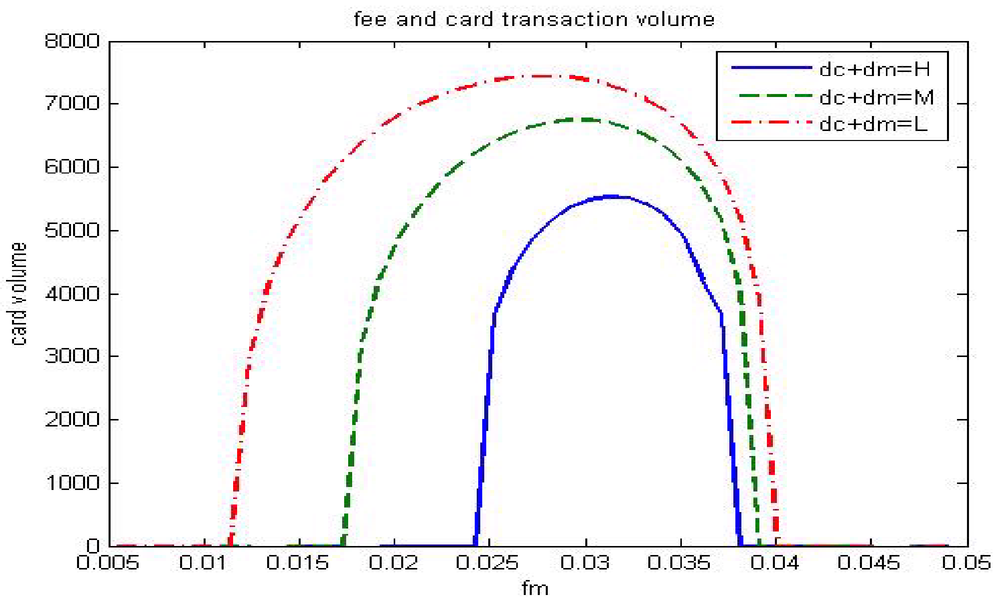

Figure 5: Cost Allocation and Card Transaction Volume

- As the total card cost decreases, both card fees to merchants and consumers decrease but at different rates.

3.2.3 Monopoly Card Network

A monopoly network maximizes the card profits instead of transaction volume.

$$\underset{f_c, f_m}{Max} \;\; e^{(-\lambda I_0)}(\frac{1}{\lambda} + I_0 - k_c)(\frac{1-\alpha_0^2}{1+f_c})(f_c + f_m - d_c - d_m)$$

$$s.t. \qquad \alpha_0 = \frac{k_m(1+f_c)}{2e^{(-\lambda I_0)}(\frac{1}{\lambda} + I_0 - k_c)(\tau_m - f_m)}$$

$$I_0 = \frac{k_c}{1 - (\frac{1+f_c}{1+\tau_c})^{1-\alpha_0^2}}$$

Figure 6 shows the monopoly network profit corresponding to each card fee schedules (f_c, f_m). The monopoly will choose a point on the surface that yields the highest profit.

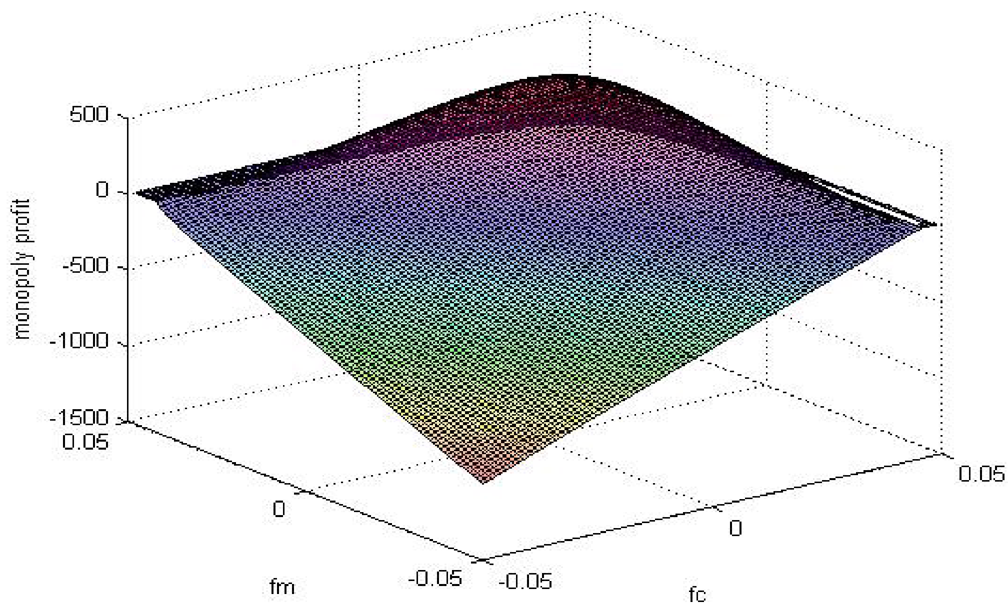

Figure 6: Card Fees and Monopoly Profit

3.2.4 Social Planner

The social planner maximizes the social surplus subject to the incentive constraints of merchants and consumers:

$$\underset{f_c,f_m}{Max} \;\; e^{(-\lambda I_0)}(1-\alpha_0^2)\{(\frac{1}{\lambda}+I_0)(\frac{\tau_c+\tau_m}{1+\tau_c})-(\frac{1}{\lambda}+I_0-k_c)(\frac{d_c+d_m}{1+f_c})\}-e^{(-\lambda I_0)}k_c-(1-\alpha_0)k_m$$

$$s.t. \quad \alpha_0 = \frac{k_m(1+f_c)}{2e^{(-\lambda I_0)}(\frac{1}{\lambda}+I_0-k_c)(\tau_m-f_m)}$$

$$I_0 = \frac{k_c}{1-(\frac{1+f_c}{1+\tau_c})^{1-\alpha_0^2}}$$

Figure 7 shows the total social surplus corresponding to each card fee schedules (f_c, f_m). The social planner will choose a point on the surface that yields the highest social surplus.

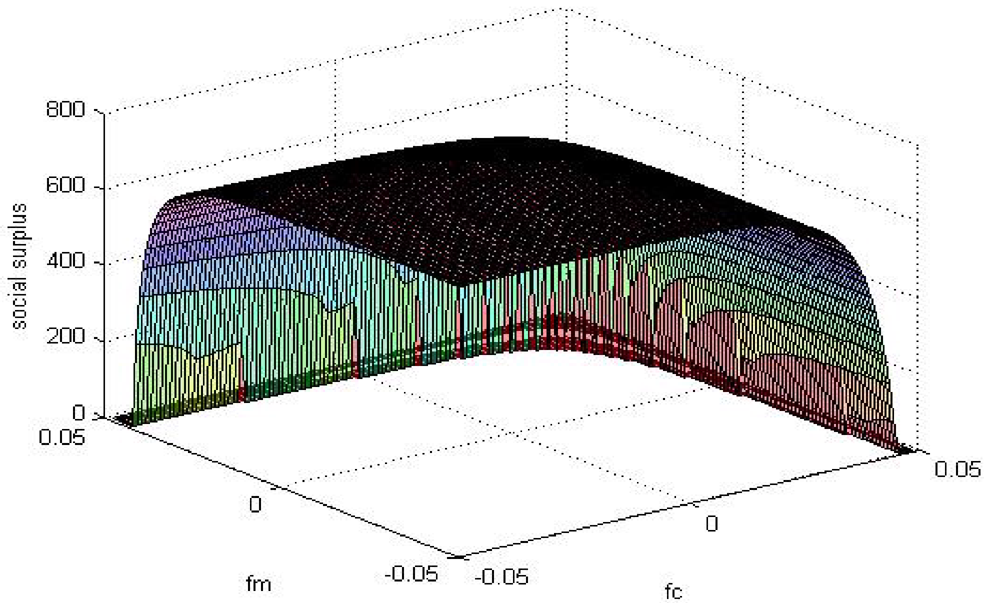

Figure 7: Card Fees and Social Surplus

3.2.5 Findings

As shown, a competitive card network, a monopoly card network, and the social planner each solves a different problem. The resulting market outcomes and competitive dynamics are well illustrated with our simulations (see attached figures in the Appendix).

Our major findings are:

- At a given total cost $d_m + d_c$, the monopoly network chooses the highest price level, ($f_m + f_c$), and, correspondingly, the lowest card adoption and usage; the social planner chooses the lowest price level ($f_m + f_c$), resulting in the highest card adoption and usage.
- As the total cost $d_m + d_c$ declines, all three market structures, competitive, monopoly and social planner, choose decreasing fees f_m and f_c and generate

more card adoption and transactions. However, the monopoly network has the smallest fee reduction while the social planner has the highest.

- The cost allocation tends to be different under different market structures. As shown in simulation 1, with a symmetric adoption cost k_m and k_c, the monopoly charges similar fees to both merchants and consumers, the competitive network charges more to merchants than consumers, while the social planner charges more to consumers than merchants.

  This is a key result and worth considering further. Consider the move from a competitive card industry structure to a monopoly one for a given level of total costs. We observe that the monopoly tends to raise prices more on consumers. Why is this? The intuition for this result can be understood by considering the first-order effects from the card-provider's optimization conditions. Consider, in the move from a competitive card-industry to a monopoly card-industry, a marginal increase in merchant fees and no change in consumer fees. The loss in revenue from transactions will consist of all the income from cards in the marginal store (that declines card acceptance after the price increase). Alternatively, consider a marginal increase in consumer fees and no change in merchant fees. The loss in revenue will consist of the loss from the marginal (low-income) consumer's transactions in all stores. Under the distributions we assume, the former loss is greater for the monopolist than the latter, so the monopolist tends to raise consumer fees relative to the competitive firm. For the move from a private organization of industry to the social planner, the social planner, in addition to valuing the card transaction, values the benefits from displaced high-cost cash transactions (the alternative payment device). It tends to weight a decrease in merchant fees more than a decrease in consumer fees because by lowering the merchant's fees, which leads to the adoption of the device by additional merchants, the social planner can displace the existing cash transactions in those additional merchants by the amount of the existing users of the device. This is a bigger effect, given our distributions, than would be a relative decrease in consumer fees.

- As consumer incomes rise relative to card service costs (e.g., total costs of card provision may decrease with technological progress or consumer incomes may increase with economic growth), consumer fees tend to be decreased relative to merchant fees. This can be understood as attempting to achieve a higher penetration rate over time, which given our income and firm-size distributions, lead to greater use of cards than would lower merchant fees. With an exponential distribution of income and a uniform distribution of firm size, there is a greater mass of potential transactions, as costs fall or incomes rise, in pushing consumer, rather than merchant adoption. This result is robust under all three different market structures.

- The fee allocation is influenced by the adoption cost k_m and k_c so that the party having a higher card adoption cost tends to bear a lower card service fee (as shown in simulations 2 and 3). This result is robust under all three different market structures.

3.2.6 Applications: Interchange Fee Puzzles

Our model provides a general framework to study the pricing, adoption and usage of payment devices. When applied to the payment card, it sheds lights on several puzzles surrounding the payment card interchange fees.

First, for some payment card systems (e.g., debit cards in the U.S.), why did the interchange fees flow from consumers to merchants in the early years only to have the direction reversed more recently? More generally, why have interchange fees increased in recent years?

As total costs of card provision is decreased, as would occur with technological progress, our model suggests that fees would decrease relatively for consumers. As we explained earlier, this can be understood as attempting to achieve a higher penetration rate over time, which given our income and firm-size distributions, lead to greater use of cards than would be to lower merchant fees. With the more-skewed income distribution, there is a greater mass of potential transactions, as costs fall, in pushing consumer, rather than merchant adoption. Furthermore, our theory suggests that consumers might have to pay interchange fees in early years under two other conditions: (1) early in the evolution of debit cards, there was a higher adoption cost k_m for merchants relative to consumers as merchants had to install new card terminals, while consumers were endowed with debit cards through their banks' delivery to them of ATM cards (which then could function as debit cards); (2) the mean consumer income $1/\lambda$ was low. Consequently, our model would suggest that consumers had to bear a larger share of the card service costs. Later on, as the merchants' adoption cost k_m declined (as general purpose credit and debit card terminals became available, and terminals fell in cost) and the mean consumer income $1/\lambda$ increased, more card cost was shifted to the merchants and the interchange fees could reverse direction.

Second, why haven't the interchange fees paid by merchants fallen rapidly with the technological progress in the U.S. as well as worldwide?

Our theory suggests it might be explained by several factors: (1) the more-skewed distribution of income leads to relative price declines for consumers over time as costs of provision fall; (2) an increase in monopoly power as the card industry matures may slow down the reduction of card service fees; (3) income growth may cause merchants to bear more card service costs relative to consumers. We believe that all factors matter given the observations that the concentration of payment card networks has been increasing, and at the same time, the card networks rely more and more on the consumer rebates to boost the card usage.

Another contribution of our theory to empirical issues is related to the relatively low interchange fees charged to grocery stores and gas stations in the U.S. relative to department stores. We would suggest that grocery stores and gas stations suffer higher adoption costs of accepting electronic payment cards relative to department stores, for example, as grocery stores and gas stations must install terminals in many more locations per dollar of sales when compared with department stores. As those particular merchants' adoption costs are higher, the consumer bears a higher share of the payment card costs in those venues than in the department stores.

4 Final Remarks

We have provided an alternative theory of two-sided market to study the pricing, adoption and use of payment devices, in which we focus on the monetary nature of payment, and emphasize the roles that consumers' income distribution and merchants' size heterogeneity play in adopting new payment devices. Unlike many existing studies, we assume a competitive economy where both merchants and consumers behave nonstrategically. The richness of the strategic approach is sacrificed in favor of a focus on the interplay between individual firm and consumer decision-making and aggregate industry characteristics. As a result, our model provides a convenient framework to study evolution of payment industry both in the short run (network "chicken-egg" dynamics) and long-run (dynamics due to cost and income changes), and offers some further insights into the related competition policy issues.

Our analyses show that consumer income, adoption cost, and market structure each play important roles in determining the pricing and usage of payment devices. In particular, when applied to the payment card industry, our findings suggest that both the increasing concentration of payment card network and the growth of consumer income relative to card service costs may help explain the puzzles surrounding interchange fees. Furthermore, our model focuses attention on adoption costs in explaining the dynamics of the direction of interchange fees in the U.S. debit card industry, and in the array of interchange fees chosen by card networks in different industries.

We suggest several extensions of the model. First, we may check the robustness of our results under alternative distribution assumptions for consumer income and firm size. Second, we may introduce sunk costs of adopting the payment devices for merchants and consumers to further address the dynamics of adoption and pricing. Third, we may model explicitly the competition among payment networks.

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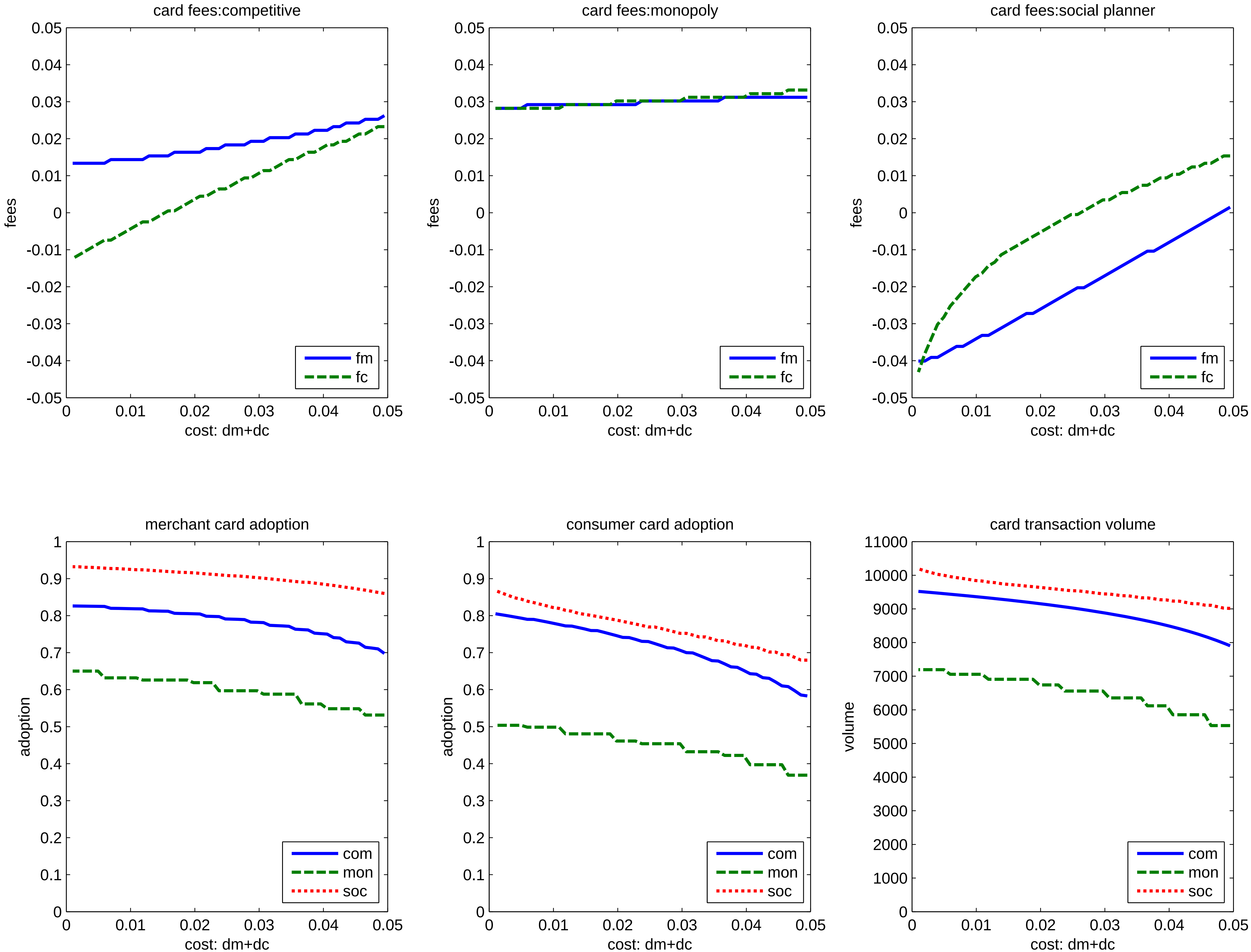
Appendix: Simulation Results



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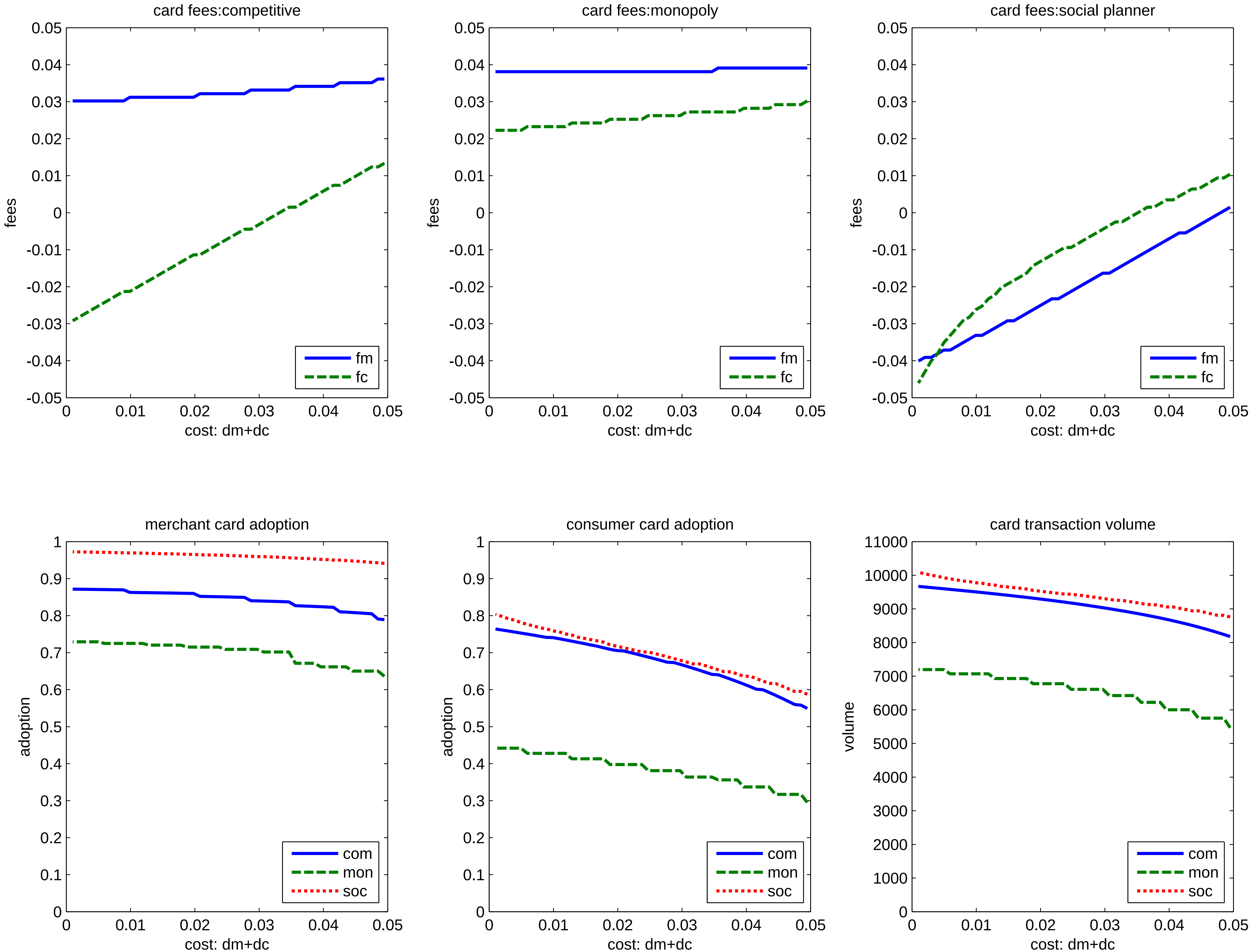

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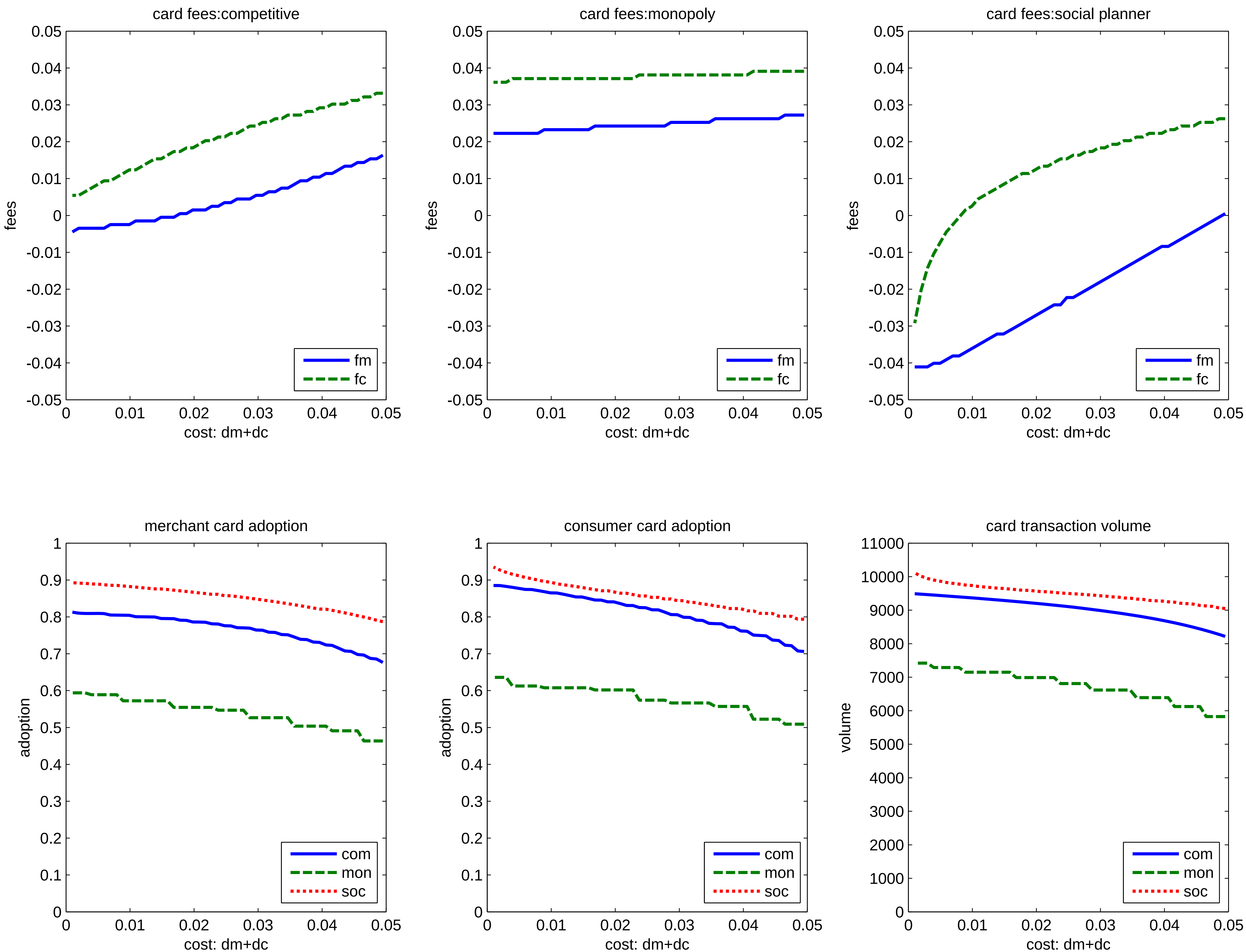

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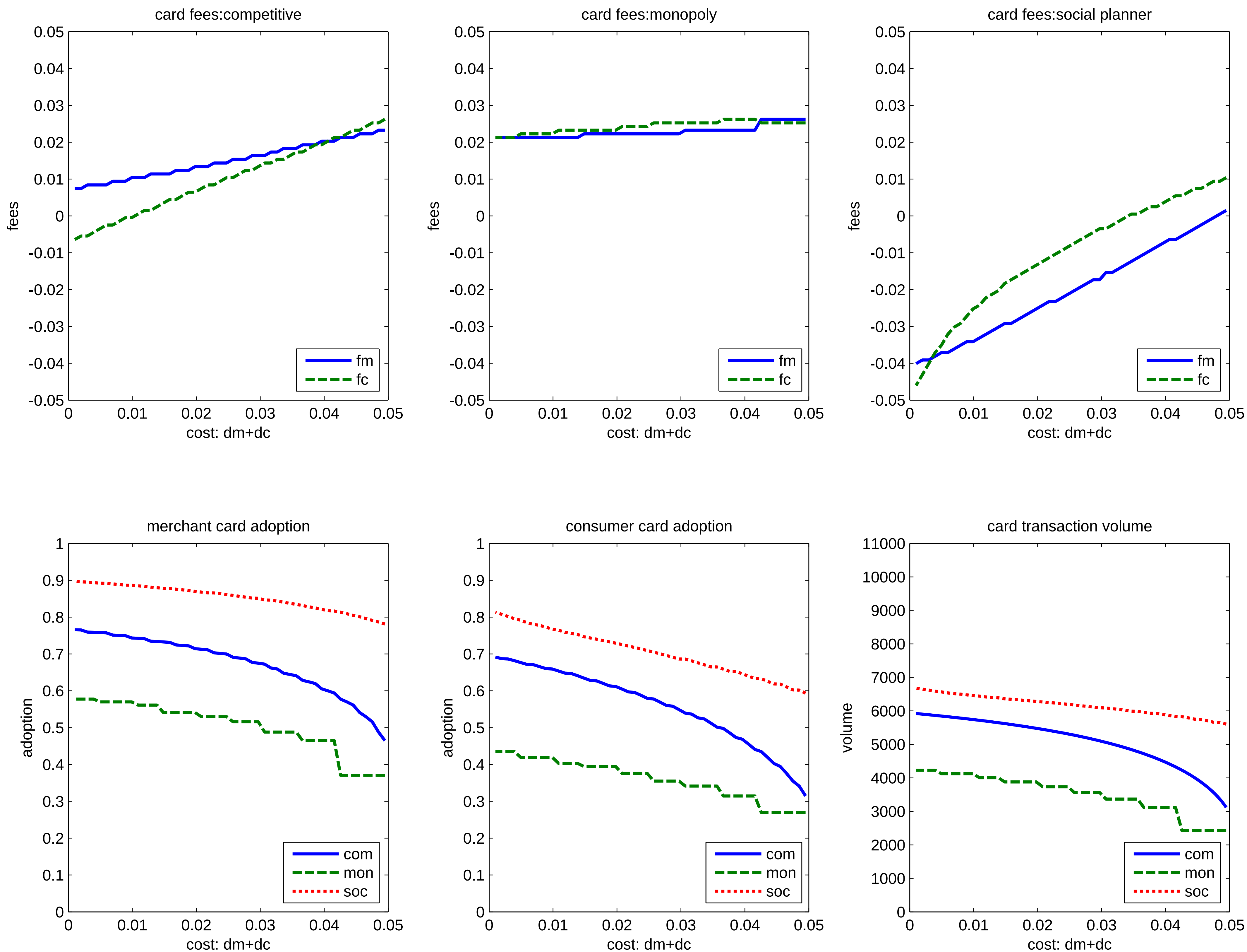

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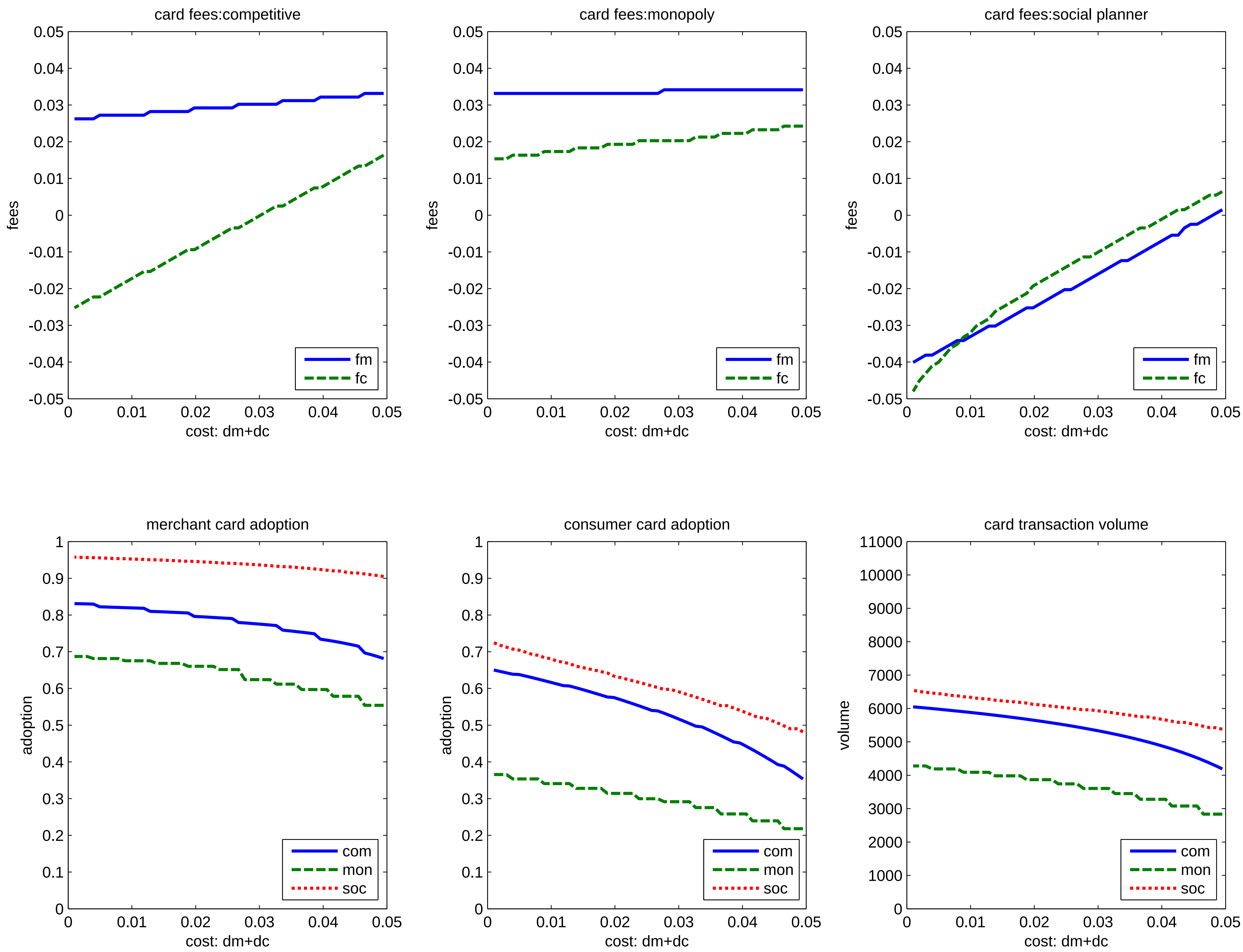

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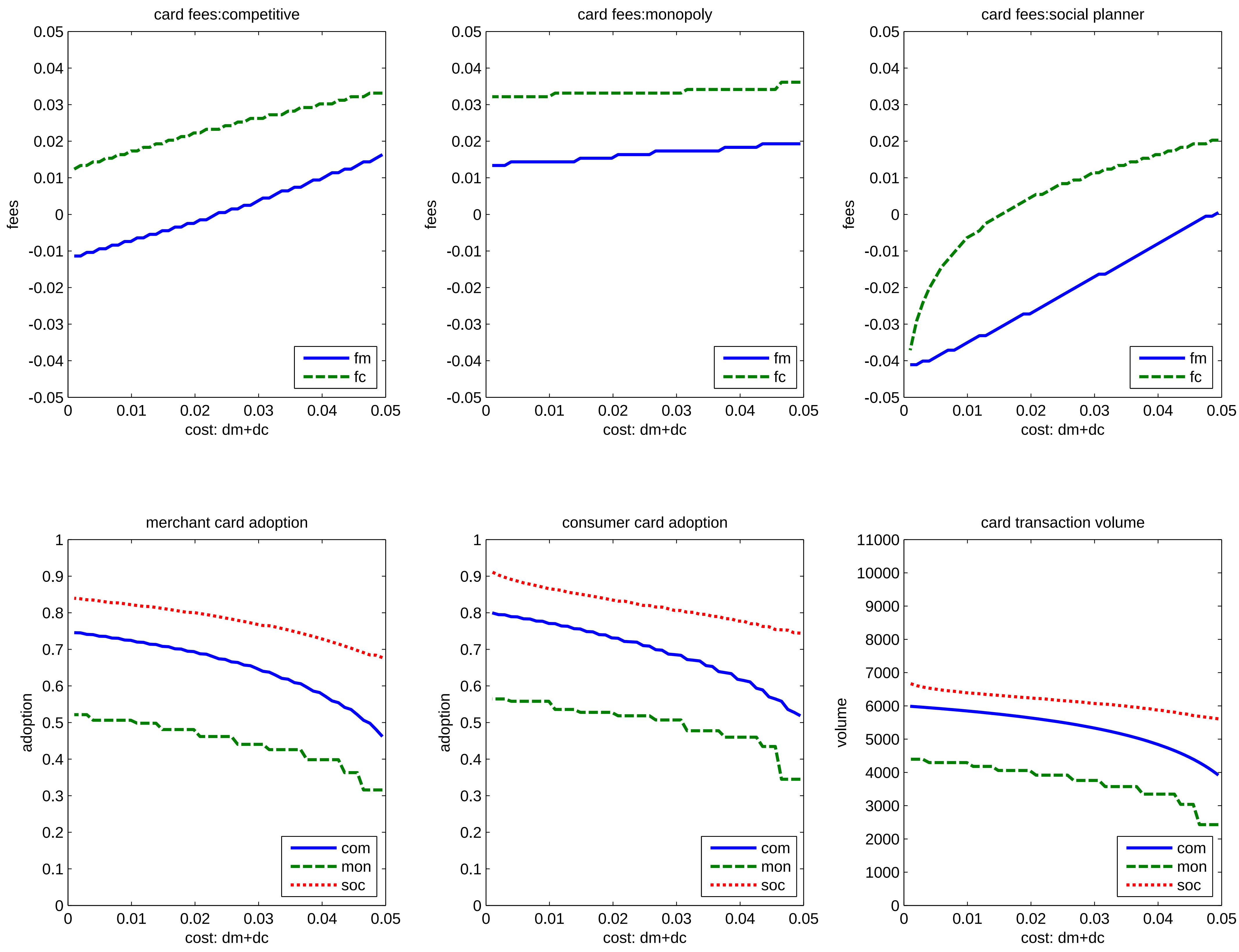

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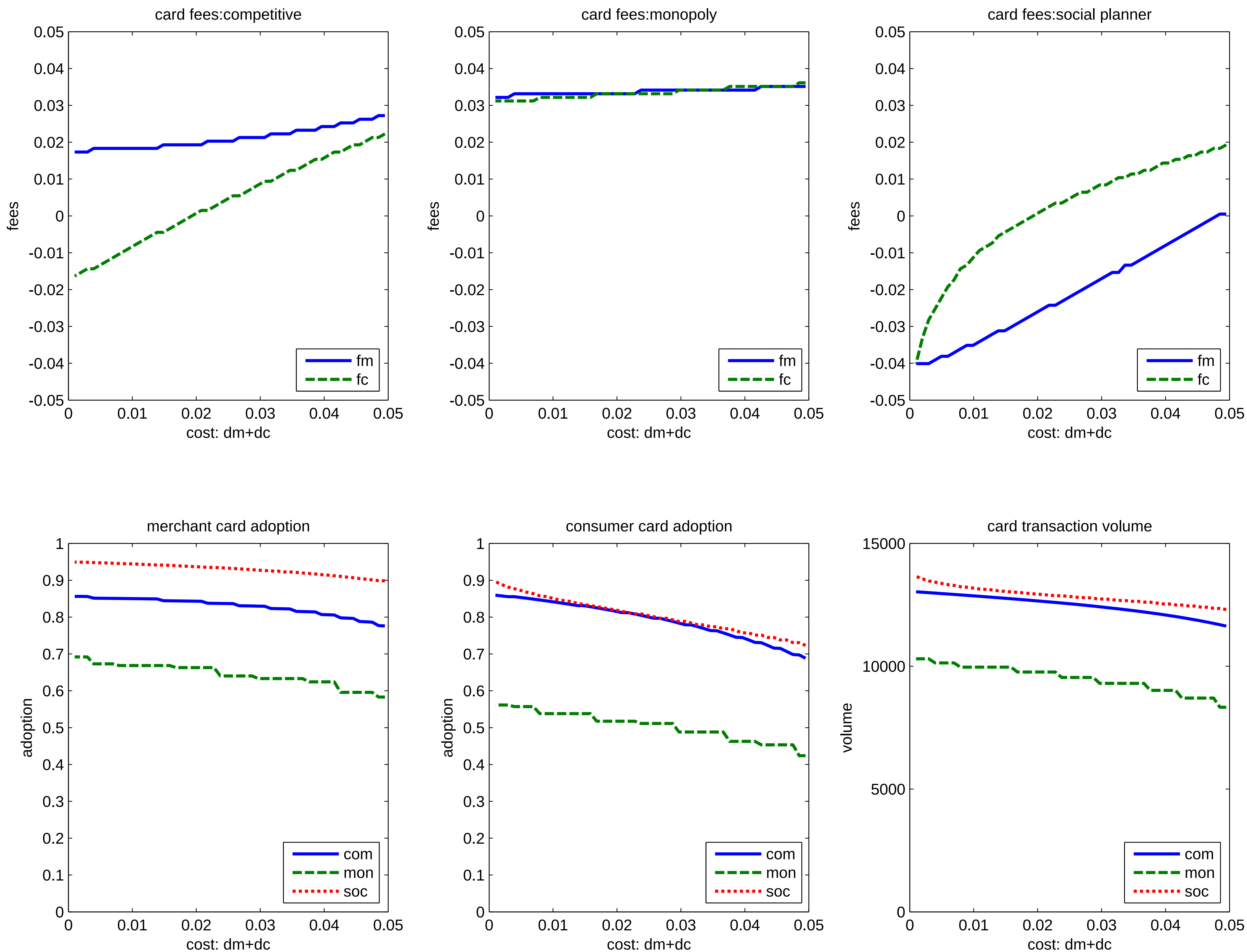

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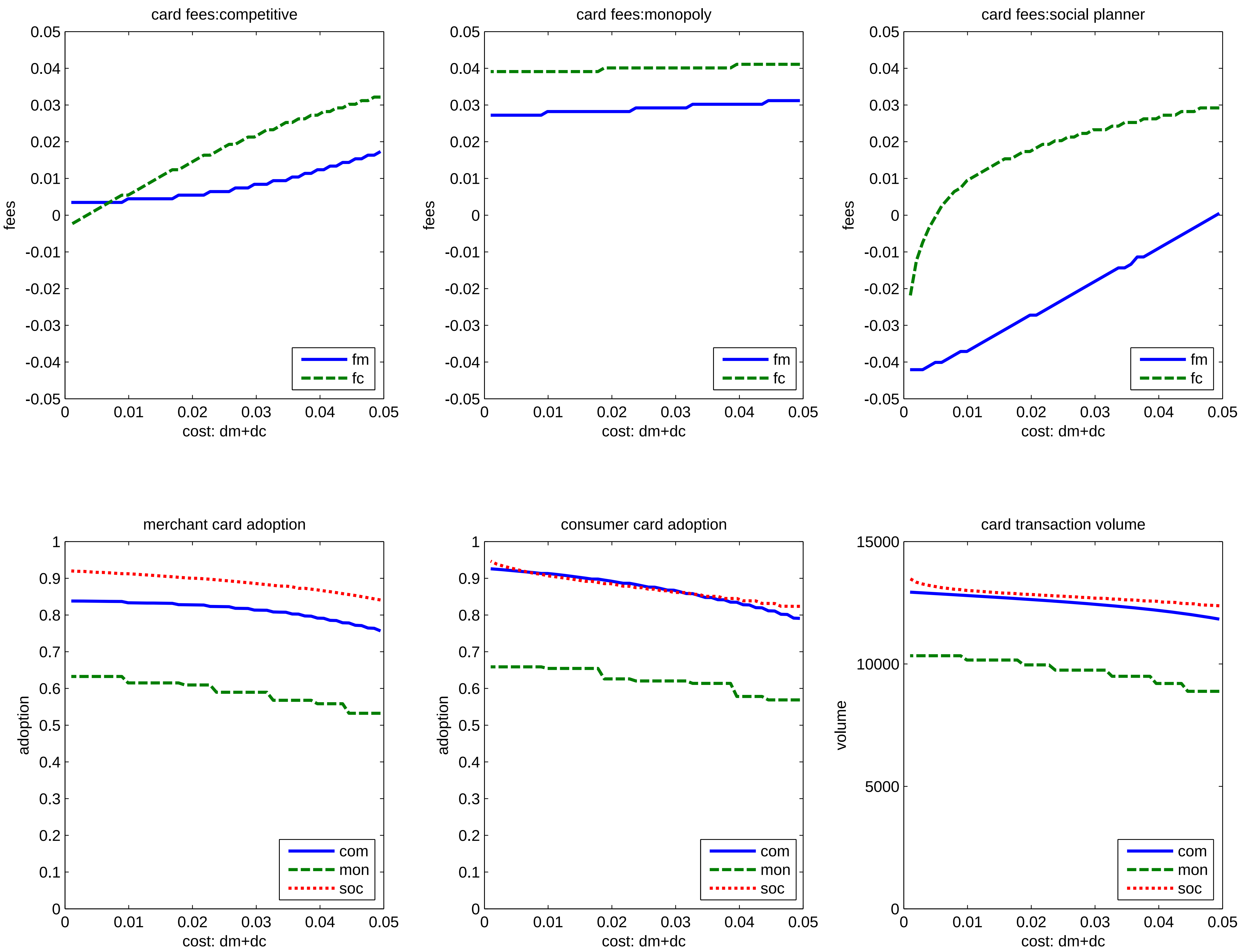
Appendix: Simulation Results



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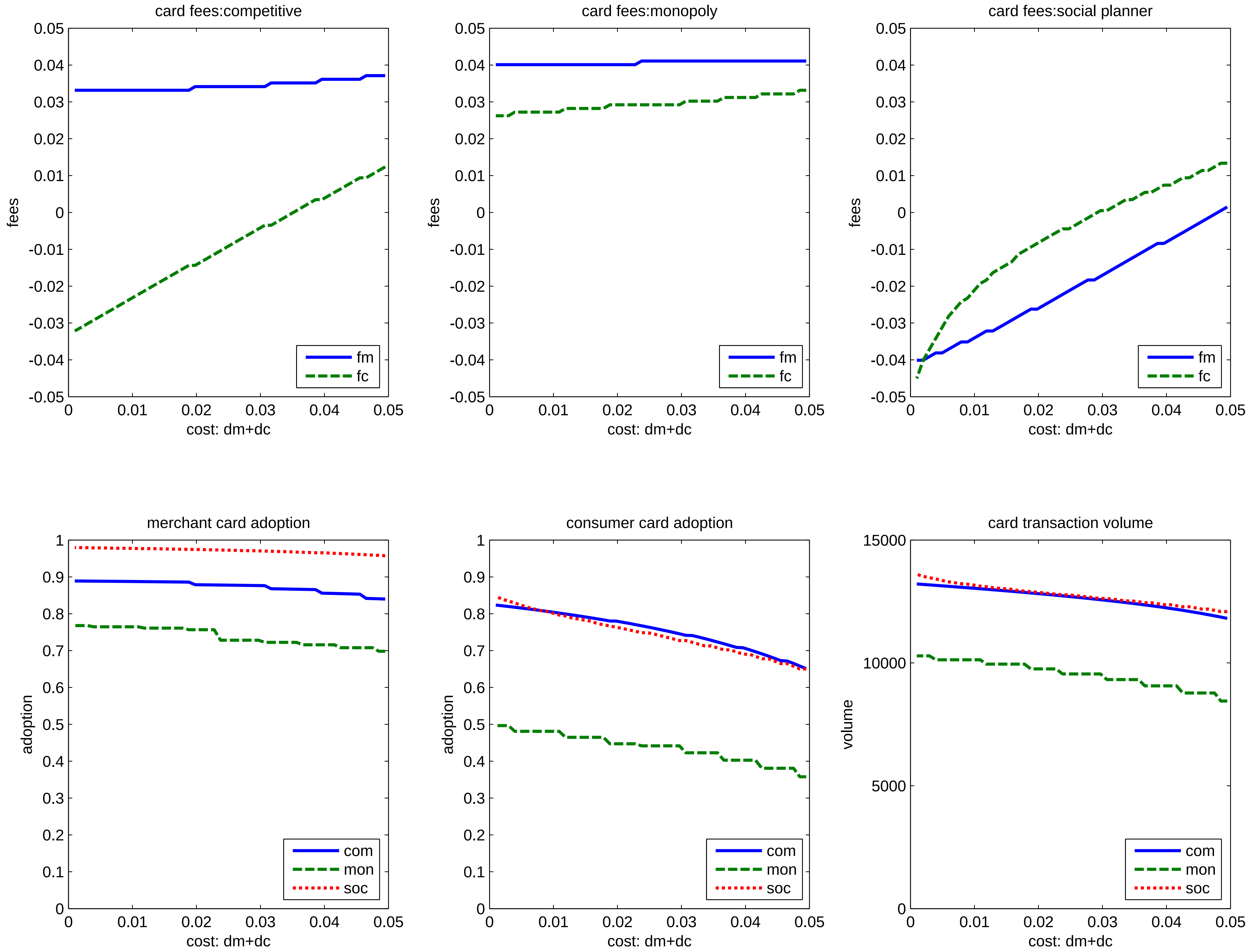
Appendix: Simulation Results



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