CESifo WORKING PAPERS

8995
2021

April 2021

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CESifo

Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editor: Clemens Fuest
https://www.cesifo.org/en/wp
An electronic version of the paper may be downloaded
· from the SSRN website: www.SSRN.com
· from the RePEc website: www.RePEc.org
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CESifo *Working Paper No. 8995*

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Abstract

Mobile payments (m-payments) increase the accessibility of large segments of society to financial services while before the traditional banking system excluded these for lack of proof of identity and because of unsafe environments. This constitutes a key driver of new growth strategies of the developing world. Smartphones are essential to perform m-payments. In that regard, recent criticism from different sides has expressed the view that manufacturers' strategies generate partial market coverage whereby the purchase of a phone and financial inclusion also remain out of reach for the group of poor consumers. Our aim in this paper is to examine the theoretical premises of this conjecture in a small open economy and uncover the conditions under which full market coverage is efficient and desirable. We analyze subgame perfect equilibria of a vertical duopoly model characterized by consumers' taste for quality. The government uses taxes and/or subsidies to modify the market equilibrium. Given this, the following issues are considered: (a) What is the impact of different standards of payment security on the equilibrium number of low- and high-quality users? (b) What are the aggregate welfare gains of complete financial inclusion? (c) What happens if phone makers are foreign?

JEL-Codes: F230, G500, H310, H620, L130, L150.

Keywords: vertical duopoly, full market coverage, technical obsolescence, financial inclusion.

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This version: 30 March, 2021
We thank B. Jacobs, A. Marchionni, C. van Marrewijk and seminar participants at Erasmus University for their helpful comments and suggestions.

1. Introduction

Traditional banking payment systems are facing fierce competition from an increasing number of competing payment instruments. While in developed countries mobile payments (m-payments) are meant to ease transactions (Trütsch, 2016), in developing countries they tend to replace and expand the traditional banking system (Aron, 2017). Particularly, m-payment services are prevalent in Southeast African countries, where these payment systems are relatively mature. Hence:

> *"Paying for a taxi ride using your mobile phone is easier in Nairobi than it is in New York..."* The Economist, March 2, 2015

M-payments increase the accessibility of the population to financial services.[1] For generations, formal financial institutions excluded large segments of society that could not provide proof of identity required to open an account. Moreover, pandemics and social unrests made it unsafe to carry cash balances and high transaction costs were imposed for holding small amounts.[2] Table 1 shows World Bank's Global Findex data on account ownerships for the age group above 15 across gender and

Table 1. Account Ownership in 2017

Region	Female	Male
East Asia and Pacific	68	73
South Asia	64	75
Europe and Central Asia	62	69
High-income OECD	94	95
Latin America and Caribbean	51	58
Middle East and North Africa	36	52
Sub-Saharan Africa	37	48

Source: *World Bank, The Global Findex Database.*
Note: *Percentage of females and males (age 15+) owning an account at a bank, or another type of financial institution, or with a mobile money provider in 2017.*

[1] M-payments are defined as payments using a mobile device, such as a mobile phone or smartphone. Mobile money (m-money) refers to money deposited in the mobile wallet. M-payments differ from online banking systems as the m-payment service is not linked to a bank account. The identification number is the phone number.

[2] See Mbiti and Weil (2011, 2013) for a description of the various informal methods of money transfers and their respective riskiness. See also Aron (2017) for an exhaustive review of the latest financial innovations in many developing countries.

across regions of the world (see also Demirguc-Kunt *et al.*, 2015). *E.g.*, only 37 percent of women and 48 percent of men own an account at a formal financial institution in Sub-Saharan Africa. Unsurprisingly, the mobile penetration rates have increased rapidly over the past decades in those parts of the world and improved coverage for mobile transactions offer new opportunities to expand financial inclusion, particularly for women and the poor.

With the arrival of m-payments, transaction costs and risks of sending and receiving domestic and foreign remittances have dramatically decreased. This enhances the financial resilience of households in the face of unexpected life events, with the ability to receive larger remittances at a higher frequency. Clearly, by facilitating the exchange of goods and services financial inclusion enhances the social wellbeing of individual users.[3] This constitutes a key driver of the growth strategies of the developing world.

Smartphones are essential to perform m-payments. Specifically, some phone makers manufacture flagship phones, others good budget ones. All have in common that they are fast enough to perform basic tasks as placing calls and sending texts and are getting pricier over time. Low-quality variants only get a few software updates of key features and more importantly of security walls.[4]

The analysis of m-payments is closely related to the concepts of partial and full market coverage. When the latter obtains, the market equilibrium for smartphones is such that all consumers are served. The opposite holds under partial market coverage when the purchase of a phone remains out of reach for the group of poor consumers. Surveys show that the high cost of a smartphone relative to individual income levels is the major constraint in accessing the latest technology in low-income countries (GSMA, 2017).

A prerequisite for full financial inclusion is full market coverage whereby phone makers create differentiated products to fulfill the specific needs of *all* consumers. Though a social planner may support this outcome, very often phone manufacturers

[3] Two recent studies highlight the potential social welfare gains of financial innovations. Jack and Suri (2014) analyze the impact of reduced transaction costs on risk sharing by consumers. While shocks reduce consumption for nonusers of mobile money, the consumption of users is unaffected. In a panel of 846 rural households, Munyegera and Matsumoto (2016) show a positive effect of mobile money access on household welfare, measured by real per capita consumption.

[4] See B.X. Chen, 'The pros and cons of getting a cheaper smartphone,' New York Times, International Edition, March 6, 2018.

have a different objective function. As a result, policy makers find it socially optimal to intervene by way of subsidies and/or taxes.

A recent IMF study repeatedly advised sub-Saharan African countries to modernize their tax administration systems and, more importantly, broaden the tax base (IMF, 2018). Some governments paid attention to the advice and, besides collecting more tax revenue from businesses, initiated specific mobile consumer taxes on devices and transactions. Others did not back the idea because of the belief that it would discourage investments in the newest technologies and the necessary spread of connectivity. Since public resources of developing economies are generally scarce, choices must be made, and the following questions are often raised: (i) Is complete financial inclusion leading to aggregate welfare gains? (ii) Should the optimal government intervention take the form of a tax on devices or subsidy instead? (iii) What are the conditions under which full market coverage arises when firms endogenously determine the market equilibrium? (iv) Does it make a difference if phone makers are foreign? An objective of this paper is to address these questions formally in an oligopoly model of vertically differentiated products in open economies.

Comparing subgame perfect equilibria, we obtain the following results: (*i)* It is socially optimal for a government to use mobile phone consumer subsidies and/or taxes to achieve full market coverage. A sufficient condition for this general result to hold is that the additional utility consumers get from making m-payments is sufficiently large; *(ii)* Financial inclusion is not achieved when low-quality phones become technically obsolete as tighter payment security standards are introduced by financial authorities; *(iii)* The main determinant of optimal subsidies or taxes and the resulting market outcome is the ownership structure of duopoly firms; (*iv*) For example, in a benchmark case where both qualities are produced by domestic firms, it is optimal for a government to achieve full market coverage with high-quality phones only. To do so, it subsidizes the high-quality producer more than the low-quality producer; *(v)* Under certain conditions, we show an equivalence result between market equilibria across all ownership structures such that only high quality is made so that full market coverage *and* full financial inclusion are reached.

The paper is organized as follows. Section 2 introduces the model. Market equilibria are analyzed in Section 3. Section 4 analyses optimal subsidies in the benchmark case where both low-quality and high-quality producers are domestic. Section 5 considers the case where the high-quality producer is foreign, and Section 6 considers the case where both producers are foreign. Section 7 concludes and discusses some remaining issues. The Appendix contains all proofs.

2. The Model

To model competition in the mobile telephony industry, we examine a production game between two firms (producers) selling phones that are vertically differentiated (see, *e.g.*, Zhou *et al.* 2002, Saggi and Sara 2008; Moraga-Gonzalez and Viaene, 2015).

Specification

In our model, product quality q_i may be one of two types $i \in \{L,\ H\}$: a phone of high quality, q_H, and a phone of low quality q_L. We assume $0 < q_L < q_H$ and denote the quality ratio by μ:

$$\mu \stackrel{\text{def}}{=} \frac{q_H}{q_L} \in (1, \infty)$$

Firms' production costs are normalized to zero. Both firms simultaneously choose prices p_L and p_H, and maximize their profits π_L and π_H.

The demand side is represented by a unit measure of consumers who decide on whether to buy a high-quality mobile phone, a low-quality one, or not to buy at all. Consumers have heterogeneous preferences that are captured by a quality-taste parameter θ. Consumer utility is quasi-linear and consists of four parts. When consumer θ buys a good of quality $i \in \{L,\ H\}$ at price p_i, she gets utility:

$$u(\theta, i) \stackrel{\text{def}}{=} q_i\theta - p_i + s_i + m_i \qquad (1)$$

Utility of not buying is normalized to zero.

Parameter θ is uniformly distributed over the interval $[0,\ \bar{\theta}]$, where the upper bound $\overline{\theta}$ represents the largest quality valuation in the economy. Typically, it is inversely related to the marginal utility of income and, thus, can be viewed as a proxy for the real income level of a given economy (Tirole, 1988). The term s_i is a subsidy that consumers may obtain from the government. Notably, $m_i \geq 0$ is the additional utility, or m-utility that consumers may derive from using mobile phones for services like m-payments. Thus, we assume that m-utility is the same for all consumers of a given product quality.

Payment Networks

The use of mobile phones for monetary transactions generate risks which need to be regulated. Though developing countries have used various legal and regulatory environments, only two types are considered here. We call them ‘payment networks’. Each network is characterized by different values of m-utility m_L and m_H.

In a first, low-security payment network, both low-quality and high-quality mobile phones allow consumers to perform m-payments. This corresponds to an environment where m-payments do not require any sophisticated technology. In this case, we set $m_L = m_H = m \geq 0$. All low-quality and high-quality mobile phone users are financially included in this scenario.[5]

In a second, high-security payment network, authorities (or the m-payment technology itself) require tougher access controls. This includes advanced security measures, encryption and authentication protocols, and other tools that ensure data protection. These techniques are only offered on high-quality phones. In this case, we set $m_L = 0$ and $m_H = m \geq 0$, and only high-quality mobile phone users are financially included; low-quality mobile phone users remain financially excluded.

Insights

Figure 1 displays consumer preferences on the unit measure of consumers and stresses the role of two important members denoted by θ_L and θ_H. First, consumer θ_L is indifferent between buying a low-quality phone and using none. Her utility (1) is zero, the utility level of not buying:

$$\theta_L = \frac{1}{q_L}(p_L - s_L - m_L) \tag{2}$$

Clearly, θ_L is increasing in the hedonic price of the low-quality phone but is decreasing in the m-utility level m_L (and potential subsidy s_L) derived from a purchase. With $\theta_L > 0$, the partial-market coverage obtains, and some consumers cannot perform m-payments. With $\theta_L \leq 0$, the market is fully covered instead, and in case of low-security network financial inclusion is maximized. It represents the extensive margin in our model.

[5] There can be a general lack of trust in the technology due to potential security breaches and frauds; we abstract away from these concerns in the paper.

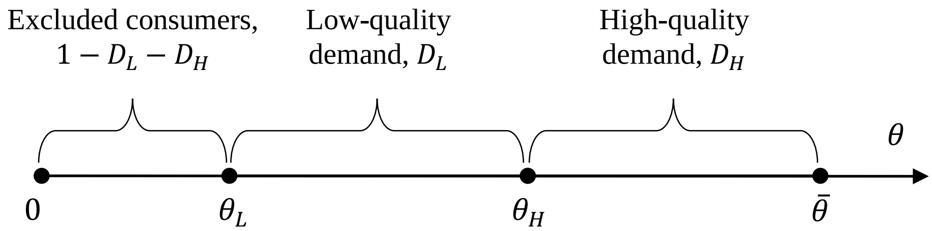

Figure 1. Consumer Preferences.

The other important consumer has a quality valuation θ_H that makes her just indifferent between the consumption of a low-quality or a high-quality phone:

$$\theta_H = \frac{1}{(\mu-1)q_L}(p_H - p_L + s_L + m_L - s_H - m_H) \tag{3}$$

Similarly, θ_H is increasing in the hedonic price of the high-quality phone but is decreasing in m-utility m_H (and potential subsidy s_H) derived from a purchase. When $\theta_H > \theta_L \geq 0$, both qualities are sold in the market. When $\theta_H = 0$, the market is fully covered by high-quality phones, which also leads to maximal financial inclusion.

When high-quality phones are required for money services, $m_L = 0$, only consumers $\theta \in [\theta_H, \bar{\theta}]$ are financially included and consumers $\theta \in [0, \theta_H)$ are financially excluded.[6] When phones of any quality are suitable for money services, $m_L = m_H$, these parameters in (3) cancel each other and consumers $\theta \in [\theta_L, \bar{\theta}]$ are financially included. In contrast, a low-quality subsidy s_L increases the position of θ_H in the interval as some consumers will replace high-quality goods with less costly alternatives, and a high-quality subsidy s_H decreases θ_H. This is the substitution effect in our model that operates when policies target a subset of consumers.[7]

Taxation

In our model, the government uses subsidies s_i to stimulate or to reduce consumer demand for either of the two qualities. It uses the corporate income tax t to finance the subsidies. When demand for product of quality $i \in \{L, H\}$ is D_i and it is sold at price p_i, the profit of producer i is $p_i D_i$, and the government tax revenue from this firm is $tp_i D_i$.

[6] To resolve a potential ambiguity, we always assume that indifferent consumers always chooses the highest-quality option from those that he is indifferent to. Since the measure of indifferent consumers is zero, this ‘tie-breaking’ rule has no consequences on the analysis, it only simplifies the notation used in the paper.

[7] Since quality level q_L enters all expressions as a multiplier for the taste parameter θ, we set $q_L = 1$ without loss of generality. As a result, parameter θ must be interpreted as consumer utility from the low-quality product.

OECD (2019) provides values for statutory corporate tax rates of 2018 by country. Table 2 reproduces some of these rates organizing the view by country groupings. Clearly, several observations emerge from Table 2. Corporate income tax rates vary widely, between 9% in Hungary and 48.3% in India but are not lower in the emerging world. However, the various tax collecting administrations may differ in their ability to enforce these rates.

Table 2. Statutory Corporate Income Tax Rates, 2018, %.

OECD countries:		**Non-OECD countries: Asia**	
France	34.4	China	25.0
Hungary	9.0	India	48.3
Ireland	12.5	Singapore	17.0
Japan	29.7	Vietnam	20.0
Non-OECD Countries: Africa		**Non-OECD Countries: Latin America**	
D.R. Congo	35.0	Argentina	30.0
Kenya	30.0	Brazil	34.0
Nigeria	30.0	Peru	29.5
South Africa	28.0	Uruguay	25.0

Source: *OECD (2019)*

Note: *Published rates are statutory corporate income tax rates exclusive of any surtax, computed after deductions for subnational taxes and inclusive of sub-central government corporate income tax rates.*

Timing of the Model and Pay-offs

The timing of the game is as follows. First, for exogenously given values of q_i (and μ), t, and $\bar{\theta}$, the domestic government determines subsidies s_i as to maximize social welfare SW. Second, given subsidies s_i, firms choose prices p_i as to maximize their after-tax profits π_i:

$$\pi_L \overset{\text{def}}{=} (1-t)p_L D_L, \pi_H \overset{\text{def}}{=} (1-t)p_H D_H \tag{4}$$

Finally, consumers make their purchasing decisions as to maximize their utility (1).

We solve the model for subgame perfect equilibria and characterize the optimal level of subsidies, the resulting market structure and equilibrium prices. Importantly, we observe whether the market is fully or partially covered. We also compute the budget surplus, and when multiple optimal subsidies exist, we select those that maximize the budget surplus.

We consider three types of firms' ownership structures, each leading to a different expression of social welfare SW: (1) all phones are produced locally by domestically-owned firms; (2) while the low quality is produced by a locally-owned firm the high-quality phone is produced abroad by a foreign-owned firm; (3) all phones are produced abroad by foreign-owned firms. These cases have their own empirical importance in the developing world. Case (1) is the dream outcome for policymakers who implement industrial and import-competing policies. It is also a useful benchmark in that all derivations and results collapse to this equilibrium when after-tax profits are not repatriated abroad. An example in support of case (2) is Cellprime Distribution Corporation, a Filipino firm, that claimed to be the first producer in the Philippines of smartphones that are entirely homemade while facing stiff foreign competition. In support of case (3), Mara Corporation, headquartered in Dubai, launched several models of smartphones aimed at covering the African continent.

3. Market Equilibria

As indicated earlier, the price competition stage is characterized by two marginal consumers, θ_L and θ_H. Depending on their values given by expressions (2) and (3), the following three market outcomes are possible:

- If $\bar{\theta} > \theta_H > \theta_L > 0$ the market is only partially covered. We refer to this outcome as the 'Partial Market Coverage mode' or *P-mode* hereinafter. Both firms make sales and their market demands are:

  $$D_L = \frac{1}{\bar{\theta}}(\theta_H - \theta_L), D_H = 1 - \frac{\theta_H}{\bar{\theta}} \tag{5}$$

  Consumers $\theta \in [0, \theta_L)$ buy neither of the goods.
- If $\bar{\theta} > \theta_H > \theta_L = 0$ the market is fully covered by both products. We refer to this outcome as the 'Full Market Coverage mode' or *F-mode* hereinafter. Both firms make sales and their market demands are:

  $$D_L = \frac{\theta_H}{\bar{\theta}}, D_H = 1 - \frac{\theta_H}{\bar{\theta}} \tag{6}$$
- If $\theta_H = 0 \geq \theta_L$ the market is fully covered by high-quality product only. This outcome is referred to as the 'High-Quality Full Market Coverage mode' or *H-mode* hereinafter. The high-quality firm sells to all consumers, $D_H = 1$, and the low-quality firm makes no sales, $D_L = 0$.[8]

[8] We do not describe other market outcomes (*e.g.*, where $\theta_H \geq \bar{\theta}$, $\theta_H \geq \theta_L > 0$, $\theta_L > \theta_H$, or $\theta_H < 0$ *etc.*) because they will not occur in a socially optimal equilibrium.

The rest of this section provides a general characterization of the market equilibrium in all three modes. Particularly, the following lemma derives market equilibrium prices, outcomes that will be used later in the implementation of the welfare analysis.

Lemma 1.

1. In the P-mode where $\bar{\theta} > \theta_H > \theta_L > 0$, equilibrium prices are:

$$p_L = \frac{1}{(4\mu-1)}\Big((\mu-1)\bar{\theta} + (2\mu-1)(s_L + m_L) - (s_H + m_H)\Big) \tag{7}$$

$$p_H = \frac{1}{(4\mu-1)}\Big(2\mu(\mu-1)\bar{\theta} - \mu(s_L + m_L) + (2\mu-1)(s_H + m_H)\Big) \tag{8}$$

2. In the F-mode where $\bar{\theta} > \theta_H > \theta_L = 0$, equilibrium prices are:

$$p_L = (s_L + m_L) \tag{9}$$

$$p_H = \frac{1}{2}\Big((\mu-1)\bar{\theta} + (s_H + m_H)\Big) \tag{10}$$

3. In the H-mode where $\theta_H = 0 \geq \theta_L$, equilibrium prices are:

$$p_L = 0 \text{ and } p_H = (s_H + m_H) - (s_L + m_L) \tag{11}$$

The proof is included in the Appendix to facilitate the reading. In this lemma, market equilibrium prices follow the standard comparative statics. In the absence of subsidies and m-utilities, the P-mode realizes (part 1 of the lemma) where the price for high quality is higher than the price for low quality. An increase in the subsidy or m-utility levels in one segment of the market positively affects the price in that segment and negatively affects the price in the other segment.

When subsidies or m-utilities increase sufficiently such that (2) violates the P-mode condition $\theta_L > 0$, the F-mode realizes (part 2 of the lemma) with $\theta_H > \theta_L = 0$. At this point, any further increase in subsidies or m-utilities has only a local effect on their own price. The reason is that the low-quality firm is at the corner solution of its profit maximization problem.

When the subsidy or m-utility in the high-quality segment increases more than in the low-quality segment, the H-mode realizes (part 3 of the lemma). At this point, the whole market is served by the high-quality firm. The low-quality firm charges a zero price, which prevents the high-quality firm from raising p_H above its equilibrium level. A crucial parameter in expressions (7) – (10) is the product differentiation parameter μ. When $\mu = 1$, both firms compete *à la* Bertrand and prices are at their lowest level. In the limit, for very large values of μ, p_H is about twice as large as p_L in the P-mode.

4. The Benchmark Case: Domestic Producers

Total social welfare SW can be expressed as the sum of social welfare SW_i generated in market segment $i \in \{L, H\}$, the low- and high-quality market segment respectively:

$$SW \stackrel{\text{def}}{=} SW_L + SW_H$$

When both producers are domestic, social welfare in each market segment consists of consumer surplus, tax revenues net of subsidies, and domestic firms' after-tax profits:

$$SW_L \stackrel{\text{def}}{=} \frac{1}{\bar{\theta}} \int_{\theta_L}^{\theta_H} (q_L\theta + m_L + s_L - p_L)\, d\theta + (tp_L - s_L)D_L + (1-t)p_L D_L \qquad (12)$$

$$SW_H \stackrel{\text{def}}{=} \frac{1}{\bar{\theta}} \int_{\theta_H}^{\bar{\theta}} (q_H\theta + m_H + s_H - p_H)\, d\theta + (tp_H - s_H)D_H + (1-t)p_H D_H \qquad (13)$$

Since consumer prices p_i, subsidies s_i, and tax revenues are just monetary transfers between economic agents, they cancel out in (12) and (13) so that the expression for social welfare SW simply becomes the sum of gross consumer utilities from low- and high-quality consumptions:

$$\begin{aligned} SW &= \frac{1}{\bar{\theta}} \int_{\theta_L}^{\theta_H} (\theta + m_L) d\theta + \frac{1}{\bar{\theta}} \int_{\theta_H}^{\bar{\theta}} (\mu\theta + m_H) d\theta \\ &= \frac{1}{2\bar{\theta}} \Big((\theta_H^2 - \theta_L^2) + \mu(\bar{\theta}^2 - \theta_H^2) \Big) + \frac{1}{\bar{\theta}} \Big((\theta_H - \theta_L)m_L + (\bar{\theta} - \theta_H)m_H \Big) \end{aligned} \qquad (14)$$

This last expression is sufficiently general to describe our three market equilibrium modes: the P-mode where $\bar{\theta} \geq \theta_H > \theta_L > 0$, the F-mode where $\theta_L = 0$ and the H-mode where $\theta_L = \theta_H = 0$. Finally, the government budget B consists of tax revenues net of subsidies:

$$B = t(p_L D_L + p_H D_H) - (s_L D_L + s_H D_H) \qquad (15)$$

Given this, the social welfare maximization problem of the government consists in determining two policy instruments, s_L and s_H, that in turn optimally affect marginal consumers θ_L and θ_H such that SW in (14) is maximized. Proposition 1 outlines the optimization result in this case.

Proposition 1.

Let both firms be domestic and let $m_H \geq m_L \geq 0$. Then, at optimal subsidies, the market is fully covered by the high-quality variant, thus $\theta_H = 0 \geq \theta_L$. The lowest optimal subsidies and the resulting market outcome are:

$$s_L = -m_L \leq 0 \text{ and } s_H = (\mu - 1)\bar{\theta} - m_H \lesseqgtr 0; \qquad (16)$$

$$p_L = 0 \text{ and } p_H = (\mu - 1)\bar{\theta};\ D_L = 0 \text{ and } D_H = 1;$$

$$B = m_H - (1-t)(\mu - 1)\bar{\theta};\ SW = \frac{\mu}{2}\bar{\theta} + m_H.$$

The proof of Proposition 1 is included in the Appendix. In this setting, we obtain a very general result, namely that all consumers are financially included irrespective of whether the payment network is of low- or high-security. It is always socially optimal to select s_L and s_H such that all consumers purchase a high-quality mobile phone, *i.e.*, to position the market into H-mode with $\theta_H = 0$. Subsidy s_L is non-positive and such that the low-quality firm charges a zero price yet does not sell. Subsidy s_H is such that the high-quality firm finds it profitable to serve the whole market and does not raise its price p_H above its equilibrium level. Any attempt to do so would lead to a positive demand for low-quality products as poor consumers would substitute expensive high-quality phones by low-quality ones, making this deviation non-profitable for the high-quality firm.

The difference between payment networks is inessential when both firms are domestic. Since the low-quality firm sells nothing, m-utility m_L does not affect market equilibrium prices, demands, the government budget and social welfare. M-utility m_H, on the other hand, is fully internalized by the government: any increase in m_H leads to the same decrease in subsidy s_H leaving market prices and demands unchanged. As a result, the government budget and social welfare increase by the same amount.

When $m_H = m_L = 0$, the aggregate subsidy $s_H D_H$ is positive and is also larger than the tax revenue:

$$s_H D_H = p_H D_H > (1-t) p_H D_H$$

The government runs a public deficit ($B < 0$) that is increasing in μ. As μ increases, the high-quality product becomes more valuable to consumers and the high-quality producer raises its price p_H. A larger subsidy s_H is then required to maintain full market coverage by high quality.

5. High-Quality Production Abroad

When the high-quality producer is foreign, the expression for social welfare SW has the following form:

$$\begin{aligned} SW &= \frac{1}{\bar{\theta}}\left(\int_{\theta_L}^{\theta_H}(\theta + m_L)\, d\theta + \int_{\theta_H}^{\bar{\theta}}(\mu\theta + m_H)\, d\theta\right) - (1-t)\pi_H \\ &= \frac{1}{2\bar{\theta}}\left((\theta_H^2 - \theta_L^2) + \mu(\bar{\theta}^2 - \theta_H^2)\right) + \frac{1}{\bar{\theta}}\left((\theta_H - \theta_L) m_L + (\bar{\theta} - \theta_H) m_H\right) \\ &\quad - (1-t)\frac{1}{\bar{\theta}}(\bar{\theta} - \theta_H) p_H \qquad (17) \end{aligned}$$

It differs from (14) in that net profits of the high-quality firm $(1-t)\pi_H$ are now repatriated abroad and thus subtracted from the expression. Hence, by setting $t=1$ we can backtrack (14) and the associated derivations and equilibrium.

When solving the social welfare maximization problem, the government faces the by now typical tradeoff between the two market segments and uses the two policy instruments, s_L and s_H, to affect marginal consumers θ_L and θ_H. On the one hand, lowering θ_H increases the market share of high-quality goods thereby increasing consumers' gross utility. On the other hand, this pushes price p_H up, which together with decreasing θ_H has a positive effect on profits of the high-quality producer. As after-tax profits are repatriated abroad, this causes a negative effect on SW through the last term in (17). Hence, providing all consumers with a high-quality mobile phone may not be always socially optimal.

In contrast, raising a subsidy s_L to achieve full market coverage can be done without any social welfare reduction since the low-quality producer is domestic. Raising s_L accompanied by an appropriate increase in s_H, so that p_H in (8) remains unchanged, only reduces θ_L and does not affect high-quality demand and profit. In this way, the government can achieve full market coverage without any negative effect on SW.

The full market coverage implies that the only effective choice of the government is the choice of θ_H given by (3) by using s_L and s_H in such a way that $\theta_L \leq 0$. This social welfare maximization problem has multiple solutions, and our focus is on the lowest subsidy levels that maximize social welfare. In addition, since the outcomes of social welfare maximization differ across payment networks, we analyze them separately.

a. Low-Security Payment Network

In a low-security network, we set $m_L = m_H = m$ and use superscript 'LS' to refer to the low-security payment network. Proposition 2 yields the following result:

Proposition 2.

Let the high-quality firm be foreign and let $m_L = m_H = m \geq 0$. Then, under optimal subsidies, the market is fully covered with $\theta_H > \theta_L = 0$. The lowest optimal subsidies and the resulting market outcome are:

$$s_L^{\text{LS}} = \frac{2(\mu-1)(1-t)}{\mu(3-2t)}\bar{\theta} - m \lesseqgtr 0 \text{ and } s_H^{\text{LS}} = -\frac{(\mu-1)(1-2t)}{(3-2t)}\bar{\theta} - m < 0; \tag{18}$$

$$p_L^{\mathrm{LS}} = \frac{2(\mu-1)(1-t)}{\mu(3-2t)}\bar{\theta} \text{ and } p_H^{\mathrm{LS}} = \frac{(\mu-1)}{(3-2t)}\bar{\theta};\ D_L^{\mathrm{LS}} = \frac{2(1-t)}{(3-2t)} \text{ and } D_H^{\mathrm{LS}} = \frac{1}{(3-2t)};$$

$$B^{\mathrm{LS}} = \frac{(\mu-1)\left(\mu-4(1-t)^2\right)(1-t)}{\mu(3-2t)^2}\bar{\theta} + m; \tag{19}$$

$$SW^{\mathrm{LS}} = \frac{\mu+2(1-t)}{2(3-2t)}\bar{\theta} + m. \tag{20}$$

The proof of this proposition is included in the Appendix. To understand its implications, let us first consider the benchmark case where $m = 0$. It is then optimal for the government to tax purchases of the high-quality phone and subsidize purchases of the low-quality variant. This optimal policy mix then leads to a budget deficit if $t < \bar{t}$, where:

$$\bar{t} \stackrel{\text{def}}{=} 1 - \frac{1}{2}\sqrt{\mu}$$

Take the lowest corporate income taxes observed in Table 2 (9% in Hungary). Then a budget deficit is avoided when $\mu > 3.28$. For the other extreme (48.3% in India) $\mu > 1.07$ would be large enough to avoid a budget deficit.[9]

When m-utility m increases, the market equilibrium remains unchanged. The reason is that a government has enough degrees of freedom, by using s_L and s_H, to offset any effect of changes in m. In other words, market shares D_L^{LS} and D_H^{LS}, as well as market prices p_L^{LS} and p_H^{LS}, are not affected by the m-utility. The low-quality producer charges a price p_L^{LS} that is equal to the sum of the subsidy s_L^{LS} and the m-utility m so that low-quality consumers get utility $u(\theta, L) = q_L\theta$. This ensures that even the lowest valuation consumer with $\theta = 0$ buys the low-quality good, *i.e.*, the market is fully covered. High-quality good consumers get net utility:

$$u(\theta, H) = q_H\theta - \frac{2(1-t)}{(3-2t)}(\mu-1)\bar{\theta}q_L$$

This reflects the cross-subsidization from high-quality to low-quality good consumption and guarantees $D_L^{\mathrm{LS}} > 0$. Interestingly, consumer utilities are independent of the m-utility m. Therefore, it is the government that fully internalizes m and as a result, the social welfare function SW^{LS} includes the m-utility m as an independent additive term.

The equilibrium described in Proposition 2 conveys additional insights. First, variables that depend on m are subsidies, the budget balance and social welfare. Second,

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[9] Interestingly, the low-quality price p_L^{LS} can be higher than the high-quality price p_H^{LS}. This happens when $t < \frac{1}{2}$ and $\mu < 2(1-t)$ and can arise for two reasons. First, these prices are factory gate prices, and government intervention creates a wedge between these and consumer prices. Second, when μ is so low, competition between firms is fierce, and firms' prices are very sensitive to subsidies. That is why the property $s_L^{\mathrm{LS}} > 0 > s_H^{\mathrm{LS}}$ of optimal subsidies can easily result in $p_L^{\mathrm{LS}} > p_H^{\mathrm{LS}}$.

a strong m-utility and/or high corporate income taxes increase the likelihood of a budget surplus. Third, irrespective of the m-utility level, both firms are active in the market, their pricing decisions and the resulting market shares are independent of it. Fourth, the equilibrium is characterized by full financial inclusion: all consumers can perform m-payments. Finally, when $t = 1$, repatriated profits of the high-quality firm become zero, and hence, this equilibrium is then identical to the case where both producers are domestic. It can be verified that the results from Proposition 1 and Proposition 2 coincide at $t = 1$.

b. High-Security Payment Network

In this scenario, only acquiring a high-quality mobile allows the consumer to perform m-payments: the low-quality variant no longer meets the security standards and is technologically obsolete. Hence, the one to one relationship between full market coverage and full financial inclusion breaks down. To show the implications of this situation, we set $m_L = 0$ and $m_H = m \geq 0$, and define a threshold utility level m^{HS}:

$$m^{\mathrm{HS}} \stackrel{\text{def}}{=} 2(1-t)(\mu-1)\bar{\theta} \tag{21}$$

where the superscript ‘HS’ refers to the high-security payment network.

Proposition 3.

Let the high-quality firm be foreign and let $m_L = 0$ and $m_H = m$. Then, at optimal subsidies, the market is fully covered. Moreover:

1. If $m < m^{\mathrm{HS}}$, the Full Market coverage realizes with $\theta_H > \theta_L = 0$. The lowest optimal subsidies, market prices, and demands are:

$$s_L^{\mathrm{HS}} = \frac{m^{HS}-m}{\mu(3-2t)} > 0 \text{ and } s_H^{\mathrm{HS}} = -\frac{(1-2t)}{(3-2t)}\Big((\mu-1)\bar{\theta}+m\Big) < 0; \tag{22}$$

$$p_L^{\mathrm{HS}} = s_L^{\mathrm{HS}} \text{ and } p_H^{\mathrm{HS}} = \frac{1}{(3-2t)}\Big((\mu-1)\bar{\theta}+m\Big); \tag{23}$$

$$D_L^{\mathrm{HS}} = \frac{e^{HS}-m}{(\mu-1)(3-2t)\bar{\theta}} \text{ and } D_H^{\mathrm{HS}} = 1 - D_L^{\mathrm{HS}}. \tag{24}$$

2. If $m \geq m^{\mathrm{HS}}$, the High-Quality Full Market coverage realizes with $\theta_H = \theta_L = 0$. The lowest optimal subsidies, market prices, demands, and the resulting budget surplus and social welfare are:

$$s_L^{\mathrm{HS}} = 0 \text{ and } s_H^{\mathrm{HS}} = (\mu-1)\bar{\theta} - m < 0; \tag{25}$$

$$p_L^{\mathrm{HS}} = 0 \text{ and } p_H^{\mathrm{HS}} = (\mu-1)\bar{\theta};\ D_L^{\mathrm{HS}} = 0 \text{ and } D_H^{\mathrm{HS}} = 1;$$

$$B^{\mathrm{HS}} = m - (\mu - 1)(1 - t)\bar{\theta} > 0;$$
$$SW^{\mathrm{HS}} = m + \tfrac{1}{2}\big(1 - (\mu - 1)(1 - 2t)\big)\bar{\theta}. \tag{26}$$

The details of the proof of this proposition are included in the Appendix. In addition, expressions for budget surplus and social welfare in the case $m < m^{\mathrm{HS}}$ being quite involving are included in the Appendix as well. The threshold m^{HS} defines an m-utility level that is just large enough for the low-quality demand to be zero, that is $D_L^{\mathrm{HS}} = 0$ in (24). For low m-utility levels, part 1 of Proposition 3 holds, otherwise part 2 is relevant.

When $m = 0$, results of Proposition 2 and Proposition 3 coincide. When $m < m^{\mathrm{HS}}$, subsidy s_L^{HS} is decreasing in m, and s_H^{HS} is a tax instead, like in Proposition 2. The market equilibrium is now affected by m, unlike Proposition 2. The price of the low-quality variant decreases in m whereas the price of the high-quality product increases in it. At the same time, the share of the low-quality product decreases in m for the following reason: with m increasing, it becomes socially optimal to provide more consumers with the high-quality product, and the government achieves this by lowering subsidy s_L^{HS}. Hence, market conditions become more favorable for the high-quality producer who charges a higher price. In contrast, the low-quality producer suffers from an increase in m.

When m increases up to the level of m^{HS}, the low-quality product disappears from the market, and only the high-quality producer makes sales. However, the low-quality firm plays a key role in equilibrium as it prevents the high-quality firm from being a monopolist. The latter cannot profitably raise its price without losing the least-valuation consumers, who will switch back to the low-quality product. Also: (i) all consumers are financially included; (ii) full technological coverage is achieved without budget deficit; (iii) apart from the subsidy (and the social welfare) levels, this outcome is identical to the case where both firms are domestic.

c. Network Security Choice

In the preceding analysis, the only role for the government was to set subsidy levels while the payment network security level remained exogenously given. However, the government may also set network security standards thereby making a choice between low-security and high-security standards for a payment network. Equivalently, this choice

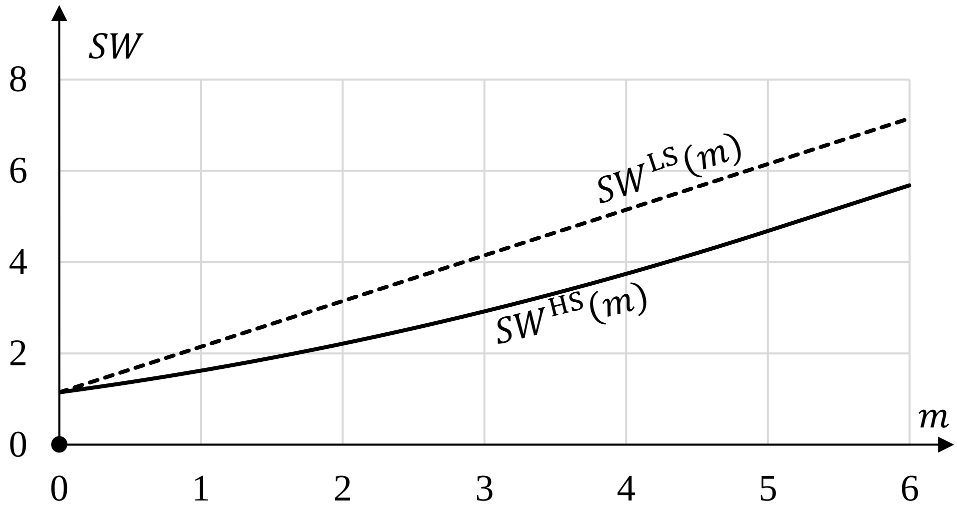

Figure 2. Social welfare functions $SW^{\mathrm{LS}}(m)$ and $SW^{\mathrm{HS}}(m)$ in low-security and high-security payment networks.

can be seen as a government decision from which consumers will benefit in terms of both type and extent of the m-utility.

For the sake of illustration, we introduce Figure 2 that depicts the social welfare functions $SW^{\mathrm{LS}}(m)$ (dashed curve) obtained from Proposition 2 and $SW^{\mathrm{HS}}(m)$ (solid curve) from Proposition 3. To that end, we make the following assumptions regarding basic model parameters: $t = 0.30$, $\bar{\theta} = 0.8$ and $\mu = 5.5$. The value for the corporate tax rate t is taken from Table 2 where an average of 30% seems reasonable, though it is known that corporate tax rates vary markedly across countries. Parameter $\bar{\theta}$ is defined as the inverse of the marginal utility of income. Empirical estimates of the latter are found in Layard *et al*. (2008) for different surveys of well-being, but a consensus estimate is 1.26, implying $\bar{\theta} \simeq 0.8$. Finally, Moraga-Gonzalez and Viaene (2005) provide numerical simulation estimates of the equilibrium product differentiation μ under a very broad range of relative costs of product development. The simulated range varying between 4 and 7, we take the average over this range, namely $\mu = 5.5$.

In Figure 2, there is no difference in the network security standards when $m = 0$, so that $SW^{\mathrm{LS}}(0) = SW^{\mathrm{HS}}(0)$. In the low-security case, $SW^{\mathrm{LS}}(m)$ is linearly increasing in m. In the high-security case, $SW^{\mathrm{HS}}(m)$ is a second-degree polynomial for $m_H \leq m^{\mathrm{HS}} = 5.04$, and it becomes linear when $m_H > m^{\mathrm{HS}}$.

It can be seen (and analytically shown) that $SW^{\mathrm{LS}}(m) > SW^{\mathrm{HS}}(m)$ for any $m \geq 0$ and any other parameter values. Hence, social welfare is higher in the low-security network for any given m-utility level. This conclusion, however, does not account for

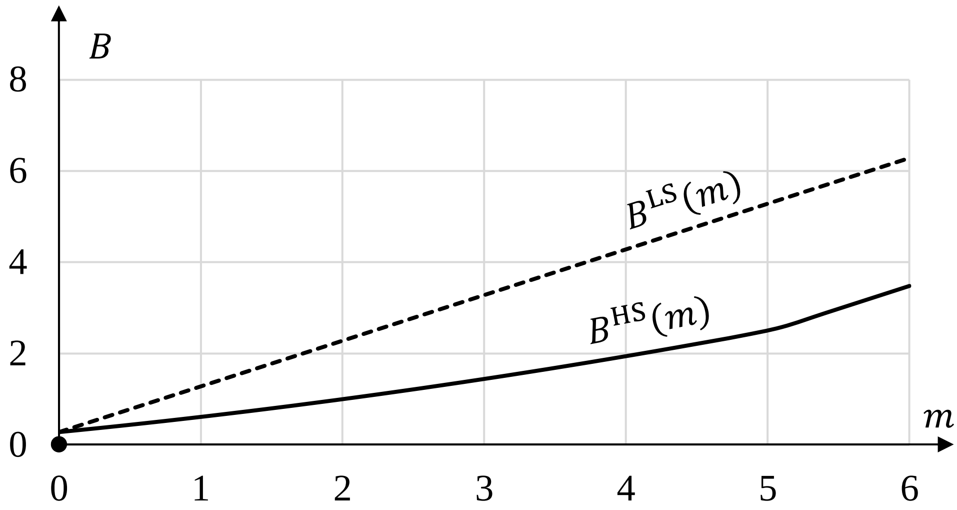

Figure 3. Budget surplus $B^{\mathrm{LS}}(m)$ and $B^{\mathrm{HS}}(m)$ in low-security and high-security payment networks.

additional costs that a low-security network may generate to society, such as banking fraud, theft, *etc*. For $m > m^{\mathrm{HS}}$, the difference in social welfare levels between low- and high-security networks is obtained by taking the difference between (20) and (26):

$$SW^{\mathrm{LS}}(m) - SW^{\mathrm{HS}}(m) = \frac{2(\mu-1)(1-t)^2}{(3-2t)}\bar{\theta} > 0$$

This difference can be interpreted as the additional social cost of the full financial coverage in the high-security network case; it obviously increases in μ.

Likewise, we can also compute the horizontal difference between social welfare functions $SW^{\mathrm{LS}}(m)$ and $SW^{\mathrm{HS}}(m)$, namely the difference Δm in m-utility levels for which social welfare levels of SW^{LS} and SW^{HS} are equal, $SW^{\mathrm{LS}}(m) = SW^{\mathrm{HS}}(m + \Delta m)$ for $m + \Delta m \geq m^{\mathrm{HS}}$:

$$\Delta m = \frac{2(\mu-1)(1-t)^2}{(3-2t)}\bar{\theta}$$

This Δm is the benefit the high-security payment network should bring about in order to convince the government to adopt the new high-security technology.

Similarly, Figure 3 depicts budget surplus functions $B^{\mathrm{LS}}(m)$ (dashed curve) from Proposition 2 and $B^{\mathrm{HS}}(m)$ (solid curve) from Proposition 3, using the same model parameters as in Figure 2. When $m = 0$, there is no difference in the network security standards so that $B^{\mathrm{LS}}(0) = B^{\mathrm{HS}}(0) > 0$, because the condition $t > \bar{t}$ holds. In the low-security case, $B^{\mathrm{LS}}(m)$ is linearly increasing in m. For any given level of m-utility, the budget surplus is higher in the low-security network. For $m > m^{\mathrm{HS}}$, the difference in the budgets between low- and high-security networks is constant:

$$B^{\mathrm{LS}}(m) - B^{\mathrm{HS}}(m) = \frac{(\mu-1)\left(1+(3-2t)^2\right)+2(3-2t)}{\mu(3-2t)^2}(\mu-1)(1-t)\bar{\theta}$$

This difference measures the additional budget expenses that are caused by the realization of the full financial coverage in a high-security network.

6. Foreign Production Only

When both low-and high-quality products are manufactured abroad, the expression for social welfare SW has the following form:

$$SW = \frac{1}{\bar{\theta}}\left(\int_{\theta_L}^{\theta_H}(\theta + m_L)\, d\theta + \int_{\theta_H}^{\bar{\theta}}(\mu\theta + m_H)\, d\theta\right) - (1-t)(\pi_L + \pi_H)$$

$$= \frac{1}{2\bar{\theta}}\left((\theta_H^2 - \theta_L^2) + \mu(\bar{\theta}^2 - \theta_H^2)\right) + \frac{1}{\bar{\theta}}\left((\theta_H - \theta_L)m_L + (\bar{\theta} - \theta_H)m_H\right)$$

$$- (1-t)\frac{1}{\bar{\theta}}\left((\theta_H - \theta_L)p_L + (\bar{\theta} - \theta_H)p_H\right) \tag{27}$$

It differs from (14) in that after-tax profits $(1-t)(\pi_L + \pi_H)$ of both low- and high-quality firms are repatriated abroad. Hence, like in the previous equilibrium, setting $t = 1$ will reproduce (14) and other associated results.

Compared to the preceding case, the social welfare maximization problem of the government is more complex for the following reason. With both firms being now foreign, any attempt to favorably modify market outcome by raising subsidies inevitably raises firms' profits. As after-tax profits are repatriated abroad, this negatively affects SW through the last term in (27). It is a standard result that in this case taxes, *i.e.*, negative subsidies, are optimal.[10] When m-utilities m_i are small, this result makes full market coverage a pipe dream. Like in Section 5, we consider low-security and high-security payment networks separately.

a. Low-Security Payment Network

In a low-security network, we set $m_L = m_H = m \geq 0$ and define another threshold m-utility level m^{LS}:

[10] This is so because marginally small taxes (negative subsidies) have a second-order negative effect on social welfare, due to the deadweight loss, and the first-order, hence dominant, positive effect on social welfare through tax revenues.

$$m^{\mathrm{LS}} \overset{\mathrm{def}}{=} \frac{4(\mu-1)(1-t)^2}{\big((\mu-1)(3-2t)+(5-4t)\big)}\bar{\theta}$$

This threshold is useful because it defines a level of m-utility such that θ_L is just equal to zero in equilibrium. Given this, Proposition 4 states the result.

Proposition 4.

Let both firms be foreign and let $m_L = m_H = m \geq 0$. Then:

1. If $m < m^{\mathrm{LS}}$, the Partial Market coverage realizes where $\theta_H > \theta_L > 0$. Optimal subsidies are unique and given by:

   $s_L^{\mathrm{LS}} = -\frac{(\mu-1)(1-2t)\big(2(1-t)\bar{\theta}+(3-2t)m\big)}{(3-2t)^2(\mu-1)+(5-4t)} < 0$, $s_H^{\mathrm{LS}} = -\frac{(\mu-1)(1-2t)\big((3-2t)\mu+2(1-t)m\big)}{(3-2t)^2(\mu-1)+(5-4t)} < 0$

   Both market prices, p_L^{LS} and p_H^{LS}, and both market demands, D_L^{LS} and D_H^{LS}, linearly increase in m. The budget balance is strictly positive, $B^{\mathrm{LS}} > 0$.

2. If $m \geq m^{\mathrm{LS}}$, the Full Market coverage realizes where $\theta_H > \theta_L = 0$. The lowest optimal subsidies are:

   $s_L^{\mathrm{LS}} = \frac{2(\mu-1)(1-t)}{\big((\mu-1)(3-2t)+(5-4t)\big)}\bar{\theta} - m < 0$, $s_H^{\mathrm{LS}} = \frac{(\mu-1)\big(1-(\mu-1)(1-2t)\big)}{\big((\mu-1)(3-2t)+(5-4t)\big)}\bar{\theta} - m < 0$; (28)

   Market prices and demands do not depend on m.

The Appendix contains the proof of this proposition together with expressions for market prices and demands. Compared to the preceding case, a small m implies that it is optimal to serve only part of the market. As m increases, the market becomes fully covered.

As long as $m < m^{\mathrm{LS}}$, both subsidies are negative (when the low-quality producer is domestic, s_L^{LS} is positive for small values of m). As a result, a budget surplus is always achieved. Moreover, it is always the case that $p_H^{LS} > p_L^{LS}$. As the m-utility increases beyond the threshold m^{LS}, the market becomes fully covered, and its outcome becomes independent of m. Both firms are active for any m-utility level, and market equilibrium is qualitatively the same as in Proposition 2 where the low-quality producer is local. Finally, it can be verified that at $t = 1$, optimal subsidies and the resulting market outcome are the same as in Proposition 1.

b. High-Security Payment Network

Consider the m-utility threshold m^{HS} defined by (21). When $m_L = 0$ and $m_H = m$, the next proposition summarizes our main results, particularly the optimal subsidies:

Proposition 5.

Let both firms be foreign and let $m_L = 0$ and $m_H = m$. Then:

1. If $m < m^{HS}$, the Partial Market coverage realizes. Optimal subsidies are as follows:

   $s_L^{\mathrm{HS}} = -\frac{(1-2t)\big(2(\mu-1)(1-t)\bar{\theta}-m\big)}{\big((\mu-1)(3-2t)^2+(5-4t)\big)} < 0,$

   $s_H^{\mathrm{HS}} = -\frac{(1-2t)\big(\mu(\mu-1)(3-2t)\bar{\theta}+\big((\mu-1)(3-2t)+1\big)m\big)}{\big((\mu-1)(3-2t)^2+(5-4t)\big)} < 0.$

   Price and demand in the low-quality segment decrease in m whereas price and demand in high-quality segment increase in m. The budget balance is strictly positive, $B^{\mathrm{HS}} > 0$.

2. If $m \geq m^{HS}$, a High-Quality Full Market coverage realizes. The optimal subsidies, market prices and demands, the budget surplus, and the resulting social welfare are as follows:

   $s_L^{\mathrm{HS}} = 0$ and $s_H^{\mathrm{HS}} = (\mu - 1)\bar{\theta} - m < 0;$

   $p_L^{\mathrm{HS}} = 0$ and $p_H^{\mathrm{HS}} = (\mu - 1)\bar{\theta}$; $D_L^{\mathrm{HS}} = 0$ and $D_H^{\mathrm{HS}} = 1;$

   $B^{\mathrm{HS}} = m - (\mu - 1)(1 - t)\bar{\theta} > 0;$

   $SW^{\mathrm{HS}} = m + \frac{1}{2}\big(1 - (\mu - 1)(1 - 2t)\big)\bar{\theta}.$

The proof is outlined in the Appendix. The latter also includes details regarding the derivations of market prices and demands. For small m-utility values, the optimal market structure is similar to the case of low-security payment network (see part 1 of Proposition 4). With a small m-utility, achieving full market coverage becomes too expensive because it requires a large subsidy for the low-quality product. As a result, the government must tax both firms, and the budget never runs into a deficit. As m increases the low-quality firm gradually decreases its price and gets a lower market share.

When $m \geq m^{HS}$ the m-utility parameter enters only expressions for social welfare, the government budget and the high-quality subsidy. Full market coverage and financial inclusion are realized. Like in the preceding section, it is possible to construct graphs like Figures 2 and 3 but the conclusion would be the same: for a given m-utility level, a high-security payment network leads to a lower budget balance and a lower social welfare level when compared to the low-security payment network. Those differences, being absent at $m = 0$, are first increasing in m, and then become constant. Thus, when both producers are foreign, a high-security payment network is preferable in terms of social welfare only if it generates sufficiently higher m-utilities. [11]

More generally, large m-utility values allow for a comparison across ownership structures. When the low-quality producer is inactive, the optimal market structure described in Proposition 5 (part 2) is identical to the case where the high-quality firm only is foreign (see part 2 of Proposition 3). Notably, the equilibrium is also identical to the case described in Proposition 1. There is thus an *equivalence* between the three production structures analyzed in this paper under a high-security payment network: (i) the high-quality full market coverage realizes; (ii) financial inclusion is achieved; (iii) the optimal subsidies, market prices and demands are all the same.

7. Discussion and Conclusion

The tremendous expansion of globalization in the last three decades has affected economies of the developing world very significantly. Its impact on communication and connectivity facilitates the arrival of mobile payments and eases the exchange of goods and services. It is in this context that we raised the following issue: is it always desirable that public funds be used to intervene in the market for mobile phones in order to foster financial inclusion? It is the main question that has been dealt with in this paper.

The answer is generally affirmative but may depend on the underlying features of the economy such as a production pattern, payment security standards, corporate income tax and consumer additional utilities derived from m-payments. Particularly, it is socially optimal for a government to use mobile phone consumer subsidies and/or taxes to achieve full market coverage. A sufficient condition for this general result to hold is that the additional utility consumers derive from m-payments is sufficiently large. Financial inclusion is always achieved except when low-quality phones become technically obsolete, *e.g.*, as a result of tighter payment security standards introduced by financial authorities. Generally, the main determinant of optimal subsidies or taxes and the

[11] This conclusion, however, can be affected by additional costs that a low-security payment network can bring about and that are excluded from our analysis.

resulting market outcome is the ownership structure of duopoly firms. Importantly, under certain conditions, we show an equivalence result between market equilibria across all ownership structures such that only high-quality phones are purchased, and full market coverage is reached.

The framework we have applied has several important features, some of which should be considered in future research. For example, though we have developed a static model its results have strong dynamic implications through financial inclusion. Clearly the latter should have a positive effect on growth, implying that income parameter $\bar{\theta}$ is no longer exogenous. Also, it has been assumed that full market coverage is technically feasible, namely that the electricity grid is large enough and cell phone signal strong enough. Our model could be used to study the impact of grid enlargement by replacing the assumption of unit measure of consumers by a measure of g consumers and increasing this parameter g. These assumptions would modify our results, but it is not yet clear to us how robust the results are when further realism to the analysis is added.

References

Aron, J. 2017. Leapfrogging: A Survey of the Nature and Economic Implications of Mobile Money. Working Paper WPS 2017-02, Center for the Study of African Economies, Oxford.

Demirguc-Kunt, A., L. Klapper, D. Singer, and P. van Oudheusden, 2015. The Global Findex Database 2014; Measuring Financial Inclusion around the World. Policy Research Working Paper 7255, World Bank.

GSMA, 2017. Accelerate Affordable Smartphone Ownership in Emerging Economies. Study funded by UK Aid and UK Government.

IMF, 2018. Sub-Saharan Africa: Domestic Revenue Mobilization and Private Investment. Regional Economic Outlook, World Economic and Financial Surveys, Washington, D.C.: International Monetary Fund.

Jack, W. and T. Suri, 2014. Risk Sharing and Transaction Costs: Evidence from Kenya's Mobile Money Revolution. *American Economic Review*, 104(1), 183-223.

Layard, R., S. Nickell and G. Mayraz, 2008. The Marginal Utility of Income. *Journal of Public Economics*, 92, 1846-1857.

Mbiti, I. and D.N. Weil, 2011. Mobile Banking: the Impact of M-Pesa in Kenya. NBER Working Paper 17129, Cambridge, Mass: NBER.

Mbiti, I. and D.N. Weil, 2013. The Home Economics of E-Money: Velocity, Cash Management, and Discount Rates of M-Pesa in Kenya. *American Economic Review*, 103(3), 369-374.

Moraga-Gonzalez, J.L. and J.-M. Viaene, 2005. Dumping in a Global World: Why Product Quality Matters? *World Economy*, 28(5), 669-682.

Moraga-Gonzalez, J.L. and J.-M. Viaene, 2015. Antidumping, Intra-Industry Trade, and Quality Reversals. *International Economic Review*, 56(3), 777-803.

Munyegera, G.K. and T. Matsumoto, 2016. Mobile Money, Remittances and Household Welfare: Panel Evidence from Rural Uganda. *World Development*, 79, 127-137.

OECD, 2019. Corporate Tax Statistics. First Edition (Paris, OECD).

Saggi, K. and N. Sara, 2008. National Treatment at the WTO: The Roles of Product and Country Heterogeneity. *International Economic Review*, 49, 1365-1394.

Tirole, J., 1988. The Theory of Industrial Organization (Boston, MA: The MIT Press).

Trütsch, T., 2016. The Impact of Mobile Payment on Payment Choice. *Financial Markets and Portfolio Management*, 30(3), 299-336.

Zhou, D., B.J. Spencer, and I. Vertinsky, 2002. Strategic Trade Policy with Endogenous Choice of Quality and Asymmetric Costs. *Journal of International Economics*, 56, 205-232.

Appendix

Proof of Lemma 1.

First, we assume the P-mode. Maximizing firms' after-tax profits (4) with demand D_i given by (5) and solving for prices p_i yields (7) and (8). Equilibrium marginal types are obtained by plugging (7) and (8) into (2) and (3):

$$\theta_H = \frac{(2\mu-1)}{(4\mu-1)}\bar{\theta} + \frac{1}{(\mu-1)(4\mu-1)}\big(\mu(s_L + m_L) - (2\mu-1)(s_H + m_H)\big) \quad (29)$$

$$\theta_L = \frac{(\mu-1)}{(4\mu-1)}\bar{\theta} - \frac{1}{(4\mu-1)}\big(2\mu(s_L + m_L) + (s_H + m_H)\big) \quad (30)$$

so that equilibrium prices can also be written as follows:

$$p_L = \frac{(\mu-1)}{\mu}(\theta_H - \theta_L) \text{ and } p_H = (\mu-1)(\bar{\theta} - \theta_H) \quad (31)$$

This ends part (1) of the Lemma.

Second, we assume the F-mode, where the condition $\theta_L = 0$ must be taken into account explicitly. Then, (2) implies (9), and maximizing π_H under (9) yields (10). Marginal type θ_H is obtained by plugging (9) and (10) into (3):

$$\theta_H = \frac{1}{2}\bar{\theta} - \frac{1}{2(\mu-1)}(s_H + m_H) \quad (32)$$

so that equilibrium price p_H can be written as follows:

$$p_H = (\mu-1)(\bar{\theta} - \theta_H) \quad (33)$$

This ends part (2) of the Lemma.

Third, we assume the H-mode, where the condition $\theta_H = 0 \geq \theta_L$ must be taken into account explicitly. The low-quality firm makes no sales and, therefore, must charge price $p_L = 0$, so that (3) implies (11). Equilibrium marginal types are obtained by plugging (11) into (2) and (3):

$$\theta_L = -\frac{1}{q_L}(s_L + m_L) \text{ and } \theta_H = 0.$$

This ends part (3) and the proof of the Lemma. ■

Proof of Proposition 1.

In this proof, firstly we formally show that optimal subsidies must be such that the market operates in the H-mode. Then, we show that multiple subsidies are optimal, and derive the lowest ones. Finally, we compute the outcome at these lowest optimal subsidies.

First, we assume the P-mode where $\theta_H > \theta_L > 0$. Maximization of social welfare SW given by (14) leads to the following F.O.C.s:

$$0 = \frac{\partial SW}{\partial s_i} = \frac{\partial SW}{\partial \theta_H}\frac{\partial \theta_H}{\partial s_i} + \frac{\partial SW}{\partial \theta_L}\frac{\partial \theta_L}{\partial s_i}, \text{ for } i \in \{L, H\}$$

This system of linear (in $\frac{\partial SW}{\partial \theta_i}$) homogeneous equations is not singular, it has a unique solution that is trivial and satisfies $\frac{\partial SW}{\partial \theta_i} = 0$, which can be written as follows:

$$\begin{cases}(\mu - 1)\theta_H = (m_L - m_H) \\ \qquad\quad \theta_L = -m_L\end{cases}$$

Due to $m_L \geq 0$, its solution (θ_L, θ_H) necessarily satisfies $\theta_L \leq 0$, which violates the P-mode condition $\theta_L > 0$.

Second, we assume the F-mode where $\theta_H > \theta_L = 0$. Plugging $\theta_L = 0$ into (14) and maximizing it w.r.t θ_H yields the F.O.C.:

$$(\mu - 1)\theta_H = (m_L - m_H)$$

which implies $\theta_H \leq 0$. This violates the F-mode condition $\theta_H > 0$. Therefore, the market is necessarily operating in the H-mode. According to Lemma 1, $\theta_H = 0$, $p_L = 0$, and $p_H = (s_H + m_H) - (s_L + m_L)$.

Subsidies s_L and s_H must be such that (i) the high-quality firm has no incentive to raise θ_H by raising its price p_H, and (ii) marginal consumer $\theta = 0$ gets non-negative utility. The first condition requires $0 \geq \frac{\partial \pi_H}{\partial p_H}$ at $p_H = (s_H + m_H) - (s_L + m_L)$, which leads to

$$s_H \geq (\mu - 1)\bar{\theta} - (m_L - m_H) + s_L$$

Thus, subsidy s_H must be sufficiently larger that s_L to ensure marginal consumer $\theta = 0$ prefers high quality to low quality. The second condition requires $p_H \leq s_H + m_H$, which leads to $s_L \geq -m_L$. All subsidies that satisfy these two conditions result in $\theta_H = 0$, $\theta_L = -(s_L + m_L)$, and maximize SW. The lowest subsidies (16) make these two conditions binding. Equilibrium level of market prices, demands, budget, and the social welfare follows directly from (11), (15), and (14). This ends the proof. ■

Proof of Proposition 2.

The proof follows similar arguments as the proof of Proposition 1. Firstly, we formally show that optimal subsidies must be such that the market operates in the F-mode. Then, we show that multiple subsidies are optimal, and derive the lowest ones. Finally, we compute the outcome at these lowest optimal subsidies.

First, we assume the P-mode where $\theta_L > 0$. Using (31) we write (17) as follows:

$$SW = \frac{1}{2\bar{\theta}}\Big((\theta_H^2 - \theta_L^2) + \mu(\bar{\theta}^2 - \theta_H^2)\Big) + \frac{1}{\bar{\theta}}(\bar{\theta} - \theta_L)m - \frac{(1-t)(\mu-1)q_L}{\bar{\theta}}(\bar{\theta} - \theta_H)^2$$

The F.O.C.s for social welfare maximization in the P-mode results in $\frac{\partial SW}{\partial \theta_i} = 0$. Equation $\frac{\partial SW}{\partial \theta_L} = 0$ implies $\theta_L q_L = -m \leq 0$, which contradicts the P-mode assumption $\theta_L > 0$. Therefore, at the optimal level of subsidies, the market is necessarily fully covered, and $\theta_L \leq 0$.

In the F-mode, we assume $\theta_L = 0$ and use (33) to write (17) as follows:

$$SW = \frac{1}{2\bar{\theta}}\left(\theta_H^2 + \mu(\bar{\theta}^2 - \theta_H^2)\right) + m - \frac{1}{\bar{\theta}}(1-t)(\mu-1)(\bar{\theta} - \theta_H)^2$$

The F.O.C. for social welfare maximization in the F-mode is $0 = \frac{\partial SW}{\partial \theta_H}$, and it implies

$$\theta_H = \frac{2(1-t)}{(3-2t)}\bar{\theta} \in [0, \bar{\theta}] \tag{34}$$

Therefore, $\theta_H > 0$ and the market operates in the F-mode, as we have assumed. Equating (34) and (32) yields s_H in (18). Subsidy s_L is not determined by the F.O.C. for maximization of SW. Instead, it must be chosen at the lowest level such that (i) $p_L \geq 0$, *i.e.*, $s_L \geq -m$ and (ii) the P-mode condition $\theta_L > 0$ fails, where θ_L is given by (30), *i.e.*, $s_L \geq \frac{2(\mu-1)(1-t)}{\mu(3-2t)}\bar{\theta} - m$. This leads to s_L in (18). Market prices are obtained by plugging (18) into (9) and (10). Market demands follow from (6). Evaluating (15) yields (19) and evaluating (17) yields (20). This ends the proof of the proposition. ■

Proof of Proposition 3.

The proof is similar to the proof of Proposition 2, we provide main equations only. In the P-mode with $\theta_L > 0$, the F.O.C. for maximization of (17) results in $\theta_L = -m_L \leq 0$, a contradiction. In the F-mode, we assume $\theta_L = 0$ and use (33) to write (17) as follows:

$$SW = \frac{1}{2\bar{\theta}}\left(\theta_H^2 + \mu(\bar{\theta}^2 - \theta_H^2)\right) + \frac{1}{\bar{\theta}}(\bar{\theta} - \theta_H)m - \frac{(1-t)(\mu-1)}{\bar{\theta}}(\bar{\theta} - \theta_H)^2$$

The F.O.C.s $0 = \frac{\partial SW}{\partial \theta_H}$ implies

$$\theta_H = \frac{2(1-t)}{(3-2t)}\bar{\theta} - \frac{m}{(\mu-1)(3-2t)} = \frac{m^{HS} - m}{(\mu-1)(3-2t)} \tag{35}$$

For $m < m^{HS}$, $\theta_H > 0$ and equating (35) and (32) yields s_H in (22). Subsidy s_L is chosen at the lowest level such that (i) $p_L \geq 0$, *i.e.*, $s_L \geq -m$ and (ii) the P-mode condition $\theta_L > 0$ fails, where θ_L is given by (30), *i.e.*, $s_L \geq \frac{1}{\mu(3-2t)}(m^{HS} - m)$. Hence, s_L in (22). The rest is straightforward: plugging $m_L = 0$ into (9) and plugging (22) into (10) yields (23), and (35) implies (24). The resulting budget surplus and social welfare are:

$$B^{\text{HS}} = \frac{(\mu-1)(\mu-4(1-t)^2)(1-t)}{\mu(3-2t)^2}\bar{\theta} + \frac{(2(\mu+2(1-t))\bar{\theta}+m)(1-t)}{\mu(3-2t)^2\bar{\theta}}m;$$

$$SW^{\mathrm{HS}} = \frac{\mu+2(1-t)}{2(3-2t)}\bar{\theta} + \frac{2(\mu-1)\bar{\theta}+m}{2(\mu-1)(3-2t)\bar{\theta}}m.$$

When $m \geq m^{\mathrm{HS}}$, $\theta_H \leq 0$ in (35), and the market operates in the H-mode. According to Lemma 1, $\theta_H = 0$, and (32) implies s_H in (25). Price p_H, according to Lemma 1, is

$$p_H = s_H - s_L + m = (\mu - 1)\bar{\theta} - s_L$$

and the social welfare is

$$SW = \frac{\mu}{2}\bar{\theta} + m - (1-t)\frac{1}{\bar{\theta}}\left((\mu-1)\bar{\theta} - s_L\right)$$

Social welfare is increasing in s_L, and its largest value is limited by the condition $\theta_L \leq 0$ so that $s_L \geq p_L = 0$. Hence, s_L in (25). The rest is straightforward. This ends the proof of the proposition. ■

Proof of Proposition 4.

As the proof is similar to that of Proposition 2, we provide the main equations only. In the P-mode with $\theta_L > 0$, we use (31) to write (27) as follows:

$$SW = \frac{1}{2\bar{\theta}}\left((\theta_H^2 - \theta_L^2) + \mu(\bar{\theta}^2 - \theta_H^2)\right) + \frac{1}{\bar{\theta}}(\bar{\theta} - \theta_L)m$$
$$- \frac{(\mu-1)(1-t)}{\mu\bar{\theta}}((\theta_H - \theta_L)^2 + \mu(\bar{\theta} - \theta_H)^2)$$

The F.O.C. for SW maximization imply $\frac{\partial SW}{\partial \theta_H} = \frac{\partial SW}{\partial \theta_L} = 0$, which after rewriting becomes:

$$\begin{cases} \theta_L = (\mu-1)(2(1-t)\bar{\theta} - (3-2t)\theta_H)q_L - m \\ \theta_L = 2\frac{(\mu-1)}{\mu}(1-t)(\theta_H - \theta_L)q_L - m \end{cases} \tag{36}$$

This linear system of equations w.r.t. (θ_L, θ_H) is not singular, it always has a unique solution, and the solution is linear in m. When $m = 0$, the solution satisfies all P-mode conditions $\bar{\theta} > \theta_H > \theta_L > 0$. When $m = m^{\mathrm{LS}}$, the solution satisfies $\bar{\theta} > \theta_H > \theta_L = 0$. Hence, for $m < m^{\mathrm{LS}}$ the P-mode realizes. Explicit solution for subsidies (s_L, s_H) can be obtained by solving (36):

$$\theta_H = \frac{2(1-t)\left(((\mu-1)(3-2t)+1)\bar{\theta} - m\right)}{((\mu-1)(3-2t)^2 + (5-4t))} \text{ and } \theta_L = \frac{(4(\mu-1)(1-t)^2\bar{\theta} - ((\mu-1)(3-2t) + (5-4t))m)}{((\mu-1)(3-2t)^2 + (5-4t))}$$

and then using (29) and (30). Computing market prices and demands yields

$$p_L^{\mathrm{LS}} = \frac{(\mu-1)\left(2(1-t)\bar{\theta} + (3-2t)m\right)}{(3-2t)^2(\mu-1) + (5-4t)},\ p_H^{\mathrm{LS}} = \frac{(\mu-1)\left(\mu(3-2t)\bar{\theta} + 2(1-t)m\right)}{(3-2t)^2(\mu-1) + (5-4t)},$$

$$D_L^{\mathrm{LS}} = \frac{\mu\left(2(1-t)\bar{\theta} + (3-2t)m\right)}{((3-2t)^2(\mu-1) + (5-4t))\bar{\theta}},\ D_H^{\mathrm{LS}} = \frac{\mu(3-2t)\bar{\theta} + 2(1-t)m}{((3-2t)^2(\mu-1) + (5-4t))\bar{\theta}}$$

Obtaining expressions for the budget and the social welfare is now straightforward (although quite involving algebraically). Since both subsidies are negative, budget surplus is always positive.

For $m \geq m^{\mathrm{LS}}$, the above expression for θ_L becomes negative, and the market is necessarily fully covered, and $\theta_L \leq 0$. In the F-mode, we assume $\theta_L = 0$ and use (33) to write (27) as follows:

$$SW = \frac{1}{2\bar{\theta}}\left(\theta_H^2 + \mu(\bar{\theta}^2 - \theta_H^2)\right) + m - (1-t)\frac{1}{\bar{\theta}}(\theta_H p_L + (\mu-1)(\bar{\theta}-\theta_H)^2)$$

This implies that SW decreases in p_L. To determine how p_L depends on θ_H, we note that, according to Lemma 1, s_L only affects p_L through $p_L = (s_L + m_L)$. Thus, multiple subsidies s_L result in the same level of θ_H and different levels of p_L. The lowest possible subsidy maximizes SW. The lowest value of s_L is determined by the following constraints: (i) $p_L \geq 0$, *i.e.*, $s_L \geq -m$; and (ii) the profit function π_L of the low-quality firm (4) in the P-mode must be non-increasing at optimal prices:

$$0 \geq \frac{\partial \pi_L}{\partial p_L} = \frac{\partial}{\partial p_L}\left(\frac{\theta_H - \theta_L}{\bar{\theta}} p_L\right) = \frac{1}{(\mu-1)\bar{\theta}}\left(p_H - 2\mu p_L + \mu(s_L + m) - (s_H + m)\right)$$

which implies

$$s_L \geq \frac{1}{2\mu}\left((\mu-1)\bar{\theta} - (s_H + m)\right) - m = \frac{(\mu-1)}{\mu}\theta_H - m$$

Hence, the lowest subsidy is $s_L = \frac{(\mu-1)}{\mu}\theta_H - m$ and

$$p_L = \frac{(\mu-1)}{\mu}\theta_H \qquad (37)$$

Social welfare function SW can now be written as follows:

$$SW = \frac{1}{2\bar{\theta}}\left(\theta_H^2 + \mu(\bar{\theta}^2 - \theta_H^2)\right) + m - \frac{(1-t)(\mu-1)}{\mu\bar{\theta}}(\theta_H^2 + \mu(\bar{\theta}-\theta_H)^2)$$

The F.O.C.s $0 = \frac{\partial SW}{\partial \theta_H}$ implies

$$\theta_H = \frac{2\mu(1-t)}{((\mu-1)(3-2t)+(5-4t))}\bar{\theta} \in (0, \bar{\theta}) \qquad (38)$$

Therefore, the market operates in the F-mode, as we have assumed. Equating (38) and (32) yields s_H in (28). Subsidy s_L obtains from $s_L = \frac{(\mu-1)}{\mu}\theta_H - m$. The rest is straightforward:

$$p_L^{\mathrm{LS}} = \frac{2(\mu-1)(1-t)}{((\mu-1)(3-2t)+(5-4t))}\bar{\theta} \text{ and } p_H^{\mathrm{LS}} = \frac{(\mu-1)\left(\mu+2(1-t)\right)}{((\mu-1)(3-2t)+(5-4t))}\bar{\theta};$$

$$D_L^{\mathrm{LS}} = \frac{2\mu(1-t)}{((\mu-1)(3-2t)+(5-4t))} \text{ and } D_H^{\mathrm{LS}} = \frac{\mu+2(1-t)}{((\mu-1)(3-2t)+(5-4t))};$$

This ends the proof of the proposition. ■

Proof of Proposition 5.

As compared to the proof, of Proposition 4, the F.O.C. in the P-mode (36) becomes

$$\begin{cases}\theta_L = (\mu-1)(2(1-t)\bar{\theta} - (3-2t)\theta_H)q_L - m \\ \theta_L = 2\frac{(\mu-1)}{\mu}(1-t)(\theta_H - \theta_L)q_L\end{cases}$$

Its solution is:

$$\theta_H = \frac{\big((\mu-1)(3-2t)+1\big)\big(2(\mu-1)(1-t)\bar{\theta}-m\big)}{(\mu-1)\big((\mu-1)(3-2t)^2+(5-4t)\big)} \text{ and } \theta_L = \frac{2(1-t)\big(2(\mu-1)(1-t)\bar{\theta}-m\big)}{\big((\mu-1)(3-2t)^2+(5-4t)\big)}$$

It satisfies the P-mode condition $\bar{\theta} > \theta_H > \theta_L > 0$ if $m < m^{\mathrm{HS}}$. Using (29) and (30) yields optimal subsidies. Computing market prices and demands yields:

$$p_L^{\mathrm{HS}} = \frac{2(\mu-1)(1-t)\bar{\theta}-m}{\big((\mu-1)(3-2t)^2+(5-4t)\big)} \text{ and } p_H^{\mathrm{HS}} = \frac{\big(\mu(\mu-1)(3-2t)\bar{\theta}+\big((\mu-1)(3-2t)+1\big)m\big)}{\big((\mu-1)(3-2t)^2+(5-4t)\big)};$$

$$D_L^{\mathrm{HS}} = \frac{\mu\big(2(\mu-1)(1-t)\bar{\theta}-m\big)}{(\mu-1)\big((\mu-1)(3-2t)^2+(5-4t)\big)\bar{\theta}} \text{ and } D_H^{\mathrm{HS}} = \frac{(\mu-1)\mu(3-2t)\bar{\theta}+\big((\mu-1)(3-2t)+1\big)m}{(\mu-1)\big((\mu-1)(3-2t)^2+(5-4t)\big)\bar{\theta}}.$$

Obtaining expressions for budget and social welfare is now straightforward. Since both subsidies are negative, budget surplus is always positive.

For $m \geq m^{\mathrm{HS}}$, the above expressions for both θ_L and θ_H becomes non-positive, and the market operates in the H-mode. Since the low-quality firm gets zero profit in the H-mode, optimal subsidies and the resulting market outcome is the same as in the case where the low-quality firm is domestic. This ends the proof of the proposition. ■