Slave prices and productivity at the Cape of Good Hope from 1700 to 1725: did all settler farmers profit from the trade?

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Slave prices and productivity at the Cape of Good Hope from 1700 to 1725: did all settler farmers profit from the trade?[1]

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ABSTRACT

This paper analyses the economic viability of slavery in the Cape Colony of southern Africa. It has been extensively documented that the affluence of elites was built on the importation of slaves. However, the Dutch East India Company or *Verengide Oost-indische Companje* (VOC), which administrated the colony, expressed concerns that free settlers had invested too much capital in the trade, so that some indications exist that profitability was not certain for all farmers. In this paper hedonic slave price indices and the value of their marginal productivity have been estimated, to construct annual returns, which are in turn compared with returns on other investments for the period 1700-1725. Hedonic price functions were estimated to remove the anticipated lifetime returns that slaves would yield, and to isolate buyers' perceived depreciation of the slave for one year. Cobb-Douglas production functions were estimated for average farmers, as well as at various quintiles along the distribution, to evaluate scale effects. Large farmers enjoyed high returns to slavery over most of the period, confirming the assertions that the elite used slaves profitably. Small farmers, however, did not recoup slave costs from agricultural production: this suggests either that they overinvested in slavery relative to other capital goods (e.g. ploughs or wagons), or that they used slaves profitably outside of agriculture.

Keywords: Cape Colony; Productivity of slaves; Profitability of slaves
JEL codes: J47, J21, N37

[1] This paper was previously entitled "Slave prices and productivity at the Cape of Good Hope from 1700 to 1725: did everyone win from the trade?". The authors hereby acknowledge that the previous title is insensitive towards the oppression of slaves who clearly did not win from the trade. We apologise unconditionally for this error and withdraw all versions of the paper that do not specify (as was our intention in writing this work), that this research questions whether all settler farmers profited from the slave trade.

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1 Introduction

The study of slavery is associated with strong moral considerations, given its inhumane history. Proponents of the slave trade primarily had economic benefits in mind in the form of cheap labour. If slavery was profitable, it would potentially have continued beyond its abolition on moral grounds. During the twentieth century slave profitability was a strongly debated issue in the United States of America (USA), in order to understand whether these economic objectives were in fact ever realized. The seminal work of Fogel and Engerman (1974) concluded that slavery was profitable and contributed to a lively discussion that followed among economic historians.

We turn the focus to another slave society, *viz* the eighteenth century Cape Colony. This study questions whether slavery was profitable in the context of the occupation by the Dutch East India Company or *Verengide Oost-indische Companje* (VOC) at the Cape of Good Hope, where policymakers expressly agreed that the importation of slaves was one of the primary vehicles for developing this fledgling economy. This paper explicitly focusses on the link between slave prices and micro level marginal productivity. While many authors point to the importance of slavery in developing this primarily agricultural economy, the verdict on its profitability has not been established quantitatively at a micro level up to this point[3]. Furthermore, the objective of this study is to understand whether farms of all sizes could employ slaves profitably, or whether other prerequisite conditions, such as product diversification or capital goods were necessary to achieve this success in agriculture.

The debate about the economic worth of slaves in the Cape had already started when Dominique de Chavonnes was the only member of the Council of Policy of the VOC who opposed the principle of using slave labour to develop agriculture (Holland, 1960). In 1717 he remarked that slavery would inhibit economic development since "the money spent on slavery is dead money", with large amounts of colonists' capital tied up in the trade. Chavonnes argued that wages paid to free European workers would increase the

[3] Giliomee (2004), Van Duin and Ross (1987), Guelke and Shell (1983), Fourie and von Fintel (2012), Fourie (2013), and Muller (1983). Worden (1985) estimated an annual return to slavery, though he used aggregate figures to achieve this instead of micro records (see the methodology section for more details on his estimation and results).

circulation of money and contribute to economic activity, but money spent on sick and aged slaves, as well as the upbringing of slave children, was unprofitable expenditure (or "dead money") that did not have second-round benefits for the economy, other than productivity for owners themselves. Chavonnes' assertion was contradicted much later in 1804 by Janssens, Governor of the Cape, when he remarked that "the whole industry of this country is based on the existence of slaves … Those who possess *many* slaves can easily be recognized by the condition of their farms; everything looks better and more prosperous than with those who have to work with scanty means" (quoted in Worden, 1985: 64 – emphasis added). Apparently slavery did have benefits, though Janssens' comments relate only to the case of farmers who owned a *sufficient number* of slaves to realize economies of scale. This verdict is silent on whether small farmers could also achieve profitability, or whether they (along with the slaves themselves), were losers from the trade.

In this paper we investigate whether slave prices matched the value of their marginal product (VMP). We develop a hedonic model of slave prices to decompose nominal prices into overall inflationary trends, the current (for that time) anticipated marginal productivity of slaves, and expected returns on slave characteristics over their lifetimes. We posit that this procedure removes the anticipated lifetime returns on the initial investment from prices, so that the remaining component can be compared with productivity and interest rates to assess profitability. Productivity relative to prices, slave costs and interest rates, on average, reflected a potential for expanding the slave force profitably. However, further investigation suggests that small farmers expanded their slave labour forces the most of all groups, but that their scale limited them to achieving profitable use of slaves *in agriculture*. Two potential explanations for this exist. Firstly, small farmers potentially attempted to mimic large farmers' profitable use of slaves unsuccessfully: their inability to diversify to multiple crops that could use slaves efficiently across seasons, and their lack of other physical, but complementary capital, limited the profitable employment of slaves in agriculture. Alternatively, small farmers' shortfall in slave agricultural productivity was accommodated by their profitable use in other industries or even in profitable arbitrage transactions. However, our data cannot distinguish between these two explanations, so that these possibilities are discussed in light of other evidence.

This paper proceeds as follows. Section 2 reviews the international slave profitability debate. Section 3 follows up with a discussion of slavery in the Cape Colony, while section 4 outlines the conceptual approach followed. Data sources and estimation are discussed in section 5 and are followed by a presentation of the results of the empirical analysis in section 6. Finally, section 7 concludes.

2 The profitability of slavery – a historical debate

The profitability of slavery was a much debated issue in the United States from the 1950s to 1970s. The methodological approach of scholars adapted over this time, in order to accommodate previous criticisms in confirming validity of results. The earliest contributions to the debate found slavery to be profitable (Conrad and Meyer, 1958). A seminal extension of this work supported these earlier findings, with slavery's returns exceeding those of other possible investments (Fogel & Engerman, 1974). Slave prices accurately reflected expected profits, and slaves were as productive as their paid European counterparts. These results received substantial criticism, however, based on assumptions, methodologies, and unrepresentative samples (see, for instance Gutman, 1975).

To address methodological concerns, the literature turned to the direct statistical estimation of production functions to determine the profitability of slavery (Vedder and Stockdale, 1975). Cobb-Douglas production functions have become the workhorse of this type of analysis, due to their simplicity and extensive empirical validity. However, they have not yet been applied using micro records in the context of the Cape. Early estimates included two inputs, namely, the number of slaves on each farm, and a combination of land and other capital (Vedder and Stockdale, 1975). Return calculations showed that slaves were as profitable as other agricultural inputs in Southern USA cotton production.

An investigation into the structure of slave prices in New Orleans during 1804-1862 attempts to clarify (among others) the economic rationality of the slave system (Kotlikoff, 1979). Kotlikoff focuses on explaining the structure of slave prices, and assumes that even though the level of slave prices changed over time, its structure remained time-invariant. More recent analyses of the slave data from his study present

a hedonic price index that recognizes the changing qualities of slaves that were bought over time (Levendis, 2007). Hedonic modelling of this kind is an important component of the analysis presented below, as it is able to account for the longevity of slaves and the time horizon over which slaves could yield profits for owners.

3 Slavery in the Cape Colony

This study interrogates the profitability of slavery in another pre-industrial society, the Cape Colony, which was situated in modern-day South Africa. This region is distinct because colonial authorities were not intent on establishing a large settler economy. Europeans nevertheless stayed and built viable agricultural operations at the same time that slaves became a prominent source of labour. Was slave labour profitable enough to contribute to the decision to settle permanently? Slavery in the Cape Colony has been intensively studied in the historical literature from multiple angles [see Worden (1985), Armstrong and Worden (1988), Worden and Crais (1994), Shell (1997) and Green (2013)]. Each of these studies provides a thorough historical overview of slavery at the Cape and its importance to the economy. This section firstly reviews the nature of the early Cape Colony and how its development was closely linked with the importation of slaves; secondly, the review turns to the benefits that farmers obtained from the trade.

3.1 The economy and the expansion of slavery

The Cape Colony was established in 1652 by Dutch Commander Jan van Riebeeck. It was not a political entity but a settlement that formed part of the commercial empire of the VOC. Initially, the sole intent was for the settlement to serve as a refreshment station that supplied passing ships (on their way to the the lucrative trade ports of the far East) with fresh food supplies. No plans to start an extensive colony existed, nor to allow settlement that was not directly related to VOC interests in the East. Soon, however, it became clear that the station could not satisfy the demand from ships with the small, intensive VOC-led agricultural activities in Cape Town. Hence, the company released some of its employees to farm and expand the supply of produce for its ships, but also allowed private agricultural production for subsistence purposes (Van Duin and Ross, 1987). In later periods non-VOC employees also settled the region, so that the Cape became a full-fledged colony beyond the narrow intent of the company. Free farmers

(*burghers*) were allowed to extend their operations into the interior, establishing (larger) independent farms, from which 10% of crops had to be transferred to the VOC in order to supply ships. Eventually these farmers settled permanently, being able to generate viable agricultural yields to support their private needs. The primary agricultural produce consisted of wheat, barley, rye, grapes and livestock, though wheat, wine and cattle predominated (Boshoff and Fourie, 2010).

Despite the decentralization of production to free farmers, the VOC held its grip on trade, market prices and production types: the company remained a monopsonist buyer and was the sole legal exporter of grain (Fourie, 2013). Ship traffic created demand for wheat exports to the Netherlands and the East. During the period 1740 to 1780, approximately 40% of the grain produced was exported to Dutch colonies and the Netherlands. Registered exports primarily comprised of wheat, and from 1748 wine exports were also recorded. In the 1770s grain made up around 75% of the total value of exports (estimated to be more than two hundred thousand guilders a year) (Van Duin and Ross, 1987).

The expanding economy created a demand for labour that was larger than what could be supplied locally. The native Khoikhoi were a nomadic people that did not settle the land formally, nor readily integrated as workers in fixed farming operations. However, some did join settler farms in small numbers, abandoning their nomadic lifestyles (Guelke & Shell, 1983). While small farmers, who farmed with pigs, goats and perishable produce for the ships (on what were called *market gardens*) could employ the Khoikhoi cheaply, they were not enslaved easily (Guelke and Shell, 1983, Shell, 1997). Due to the nomadic traditions of the Khoikhoi, land was initially sparsely populated, but it also meant that no stable local labour force existed by which to establish permanent agriculture.

In response, slave importation increased. The economy of the Cape Colony differed from the antebellum cotton-slave economies of the Southern States (USA) in that the latter had the ability to maintain labour supply through regional specialization (whereby agriculturally less-productive regions "produced" slaves (Conrad and Meyer, 1958)). In the Cape Colony, the supply of labour was primarily augmented through slave imports (Armstrong and Worden, 1988). Despite the difficulty of sourcing slaves locally, they

became a central part of the production process that warranted the costs of importation. In the first part of the eighteenth century, the average number of slaves per farm increased steadily, which coincided with the take-off of viticulture and wheat farming, and farming operations on extended landholdings (Green, 2013). Nevertheless, the VOC became increasingly concerned about the large amounts of capital invested by colonists in slavery, with Guelke (1974) estimating it at 13-17% of the total between 1731 and 1780, and rising to 20% in the last two decades of the century. Our study investigates an earlier period, considering whether investment in this form of capital was warranted.

[FIGURE 1 here]

In 1701, the total population in the Cape Colony [free persons (inclusive of Free Blacks), *knechten* (hired European workers), and slaves] was 2225 people. Towards the middle of the eighteenth century, this number had risen to 10259 people (Van Duin and Ross, 1987). Figure 1 shows the substantial increase in the share of slaves in the total population during the eighteenth century (excluding the Khoikhoi, who were not enumerated in the censuses). Europeans constituted more than 60% of the population at the beginning of the period, with a rapid decline to less than 40% by 1733. This demographic shift was the direct result of a decision made by the VOC policy council early in the eighteenth century to discourage the immigration of Europeans and to satisfy labour demand with slaves. As the slave population in the Cape Colony did not reproduce itself due to higher mortality than fertility, increasing the slave population was dependent on imports.

Given that female slaves were fairly old by the time of their arrival in the Cape, the fertility rate of those working for the VOC was relatively high (one in every ten women gave birth annually) (Armstrong and Worden, 1988). However, mortality among slaves was higher, and slave deaths were mostly attributable to diseases such as smallpox and measles (foreign diseases, which also killed the native Khoikhoi in large numbers in 1713). The scarcity of female slaves relative to male slaves also inhibited reproduction, which required constant importation to maintain the labour force. In 1706 the ratio of male to female slaves was 650 males to 100 females; this ratio subsequently declined, but only stabilized after 1875 (Shell, 1997).

Slaves originated from many parts of the world (Worden, 1985; Armstrong and Worden, 1988). Between 1652 and 1808, approximately 63000 slaves were imported predominantly from four regions, namely other parts of Africa (26.4%), India (25.9%), Madagascar (25.1%) and Indonesia (22.7%) (Shell, 1997). In 1658 the first significant number of slaves was imported to the Cape in two shiploads, one a Company voyage with 228 slaves from Dahomey, and the other with 174 Angolan slaves seized from a Portuguese slaver (Armstrong and Worden, 1988)[4]. A more significant source was Company-sponsored voyages to Mozambique, Madagascar and, later on, the East African coast (Armstrong and Worden, 1988). During the period 1652 to 1795, about 65% of the total number of slaves from these voyages originated from Madagascar (Armstrong and Worden, 1988).

Company ships that travelled from Batavia (modern-day Jakarta, the centre of the VOC's commercial interests in the East) and Ceylon on their way to the Netherlands also provided slaves, as did foreign ships on their way to the Americas. Some slaves were sold in the Cape if the immediate transaction had an advantage over anticipated prices in the New World (Shell, 1997). Furthermore, this hedged against the risk of slave death during the Atlantic crossing. These slaves were caught, for instance, in Malawi and Madagascar (Nunn, 2008)[5].

More than 95 percent of slaves arrived at the Cape in the "good months" between December and June, when the southeaster brought returning fleets to the Cape. Farmers from the interior, who missed these fleets, paid much higher prices for their slaves in the winter months, when few (if any) ships called. Slaves were especially in short supply during winter as many slaves died of ill health (Shell, 1997).

Various types of slave transactions were common. Mandatory sales occurred when sellers were obliged to sell for financial or legal reasons, or the owner repatriated or retired to Europe. Other transfers were either discretionary (such as cash sales) or donation transfers (which included manumission sales or gifts of slaves). The former category included some speculative sales, although the Cape did not have professional

[4] Dahomey was situated in the present-day Benin.
[5] Nunn (2008) produces a table that documents the origin of slaves going to the New World (1400-1900).

slave traders up to the eighteenth century (Shell, 1997). Company employees who returned to the Netherlands sold or manumitted their slaves at the Cape before their departure, because their slaves were considered free on arrival in the Netherlands, and owners were required to pay an expensive passenger fare for each slave[6]. Sometimes sales occurred at a loss, but this was better than receiving nothing (Shell, 1997).

3.2 Benefits of slavery to farmers

As slaves were relatively expensive, wealthier farmers with larger tracts of land were in a better position to buy them. The potential also existed for this group to exploit economies of scale and use slaves profitably[7]. If European labour had been used instead of slaves, smaller land areas would have been cultivated and more labour-saving technologies would have been implemented (Muller, 1983). However, after the settlers were released by Van Riebeeck, they could depart from intensive European farming practices and establish large farms on the available land, based partially on the use of slave labour (Fourie and Von Fintel, 2012). The annual return on slaves in the latter part of the eighteenth century was highest on farms with many slaves (such as grain farms), whereas small farms had smaller profit margins, since there was a relatively higher risk involved in tying up capital in slaves (Armstrong and Worden, 1988).

Farm sizes varied considerably at the Cape Colony, with the largest producing wheat. Even though farms rarely had more than 50 slaves, by the British period (1795-1910) some large estates (particularly wine and wheat) had developed (Armstrong and Worden, 1988). According to Shell (1997), Martin Melck owned 204 slaves, the largest number in the Colony[8]. Wealth, land size and slave numbers were closely linked (Dooling, 2007). Jan Blignaut, for instance, owned at least seven properties (most of them in the fertile district of Drakenstein) and eighteen slaves. Dooling (1999: 34)

[6] Slavery was illegal in the Netherlands itself, although it was allowed in its colonies (De Beer, 1993).
[7] The data used in this study does not contain information on land size for individual farmers. Where we do analyse "scale", we refer to the value of production volumes (the output), which is potentially highly correlated with plot sizes (the inputs). Additionally, we show in Tables 4 to 7 that other production inputs, such as vines planted, are highly correlated with this definition of scale. Hence, agricultural outputs are correlated with capital. We therefore assume that production volumes are good proxies for scale and capital availability. In productivity estimates we control for other proxy inputs to deal with the omission of land size from the records.
[8] Shell (1997) provides the account of a traveller, Admiral Stavorinus, of how Melck's slaves were housed – with separate housing for the married slaves.

draws an indirect link between slave ownership and the wealth of owners: "The very wealthy were typically owners of extensive landed property and an above-average number of slaves. Johannes Louw was the owner of 6 farms as well as 39 slaves, whereas Jan Martinus Coors farmed without slaves, but at his death the farm was worth a mere 63 rixdollars". These isolated cases illustrate the common thread discussed in the literature: large farmers became successful through extensive slavery, while small farmers failed because they did not invest in many slaves.

During the early eighteenth century, a close correlation developed between the number of adult male slaves owned and the output of arable farms, even though slave inputs differed according to the crop cultivated[9]. Although there were deviations, farmers that produced both wine and grain exhibited the closest correlation; more efficient exploitation of slaves resulted, as they could be put to work throughout the year when various crops were harvested. Economies of scope are therefore also likely to have influenced the profitability of slaves in farming. Fourie (2013) suggests that only the richest farmers' inventories recorded expensive capital goods that were also successfully used in non-agricultural production. Hence, their scale also allowed them to diversify.

Other possible explanations for the success of large farms include the system of property rights, cultural and social networks, large credit markets and VOC policies and practices (Fourie, 2012). This study affirms the assertion that large farmers became successful through extensive slavery; it furthermore proposes that small farmers did in fact make substantial investments in slaves, but that the costs were not covered by income from agricultural yields. The evidence presented below suggests that Chavonnes' concern with over-investment in slavery was perhaps warranted for small farmers, whose scale limited them to the unprofitable agricultural employment of slaves; however, as discussed later, this group could potentially have earned returns from slaves in other ways, so that slavery was possibly profitable in most instances.

[9] Most farmers in the wine- and grain-producing regions used more than 15 slaves, with some wine farms even using more than 80 slaves (Muller, 1983).

4 Conceptual approach

4.1 Evaluation of profitability

This section outlines the conceptual framework for evaluating the profitability of slaves. Since slaves are usually considered a substitute for scarce capital, rather than being a remunerated labour input, we evaluate profit maximization similarly to an investment that yields returns (Fourie, 2013). For it to be profitable, the initial investment (measured as the price paid for the slave, P_s) should continue to yield an annual return (in terms of the value of a slaves' marginal productivity, which is the marginal product of the slave, MP_s, multiplied by the price of the product earned in the marketplace, P_p) that is at least equivalent to the sum of the interest that a buyer would have to pay on a loan in order to buy another slave or the interest earned on alternative investments (at a rate r), the depreciation of the slave (at an annual rate d) and the annual subsistence costs of keeping slaves (such as food and clothing, c_s):

$$VMP_s = MP_s P_p = P_s(r + d) + c_s = minimum\ return\ on\ initial\ investment + subsistence\ cost \quad (1)$$

Equation (1) provides a means to assess whether the VMP was high enough for slavery to be profitable. Such comparisons require multiple sources of data: detailed price and production data are the most important to account for MP_s, P_p and P_s; additionally, archival evidence on interest rates and slave costs are required.

Depreciation is measured indirectly within a hedonic price framework, where d for the current period is isolated after current slave characteristics are controlled for (Levendis, 2007). Slave prices at the point of sale represented the *lifetime* cost of the slave to the owner which should, however, only accrue as a series of *current* expenses over the time horizon of the slave's working life. Equation (1) acknowledges the annual depreciation of slave capital, which represents the component of the initial cost that should be recovered in any given year by productivity. A time comes when slaves are no longer profitably employed, when d exceeds the productivity earned by the slave. Great variations in sale prices are recorded in any given period, as slaves with more (less) desirable "productive characteristics" fetched higher (lower) prices on the market. By implication, this better quality capital that is acquired would also take longer to

depreciate to zero profitable value, at least in the judgment of the buyer (or the slave is presumed to offer greater levels of productivity in each period). This longer time horizon until the slave is of zero productive value is captured by the positive characteristics of slaves; a longer time horizon also equates to lower levels of depreciation in any given year. For instance, a native slave would have had a longer life expectancy because of immunity to local disease (Fraginals et al. 1983). Such a slave should presumably have fetched a higher price on the market. However, this slave also offered more "lifetime productivity" to the buyer. Consequently, these slaves would also have to produce less in a given year to recoup the costs to the buyer, as these are recovered over a long time.

Most other studies account for depreciation by directly considering the expected longevity of slaves, though this type of data is not freely available for the Cape Colony (Conrad & Meyer, 1958, for instance). Implicitly, the Hedonic modelling procedure controls for life expectancy, and is required in the absence of this data. Comparisons with estimates of the VMP in those periods were therefore used to assess profitability. Returns were calculated as the ratio of VMP to purified prices, and then compared with reigning interest rates.

Worden (1985) estimated the profitability of slaves at the Cape, though the current study accounts for discrepancies that he was not able to. Our methodology differs in primarily two ways: we use micro-level data to estimate the return to slavery, and we also adjust this return by deflating it to account for lifetime returns. Worden (1985), in contrast, used average agricultural output to estimate slave productivity per unit, without controlling for any other characteristics. We heed the criticism of Vedder & Stockdale (1975) by statistical estimation of production functions, rather than the use of aggregate, unconditional rates. Worden (1985) also used average land values for different types of farms, which, combined with equipment and maintenance costs, allowed a derivation of an annual return for slaves. Since this study cannot improve on his aggregate treatment of land size with appropriate micro data, we omit this feature from our models. Instead, we add proxies for land size to productivity models (such as number of vines, seedlings planted, and other relevant inputs). Worden's (1985) findings for the latter half of the eighteenth century reflected that larger mixed farms were relatively more profitable as they could spread the capital costs across a large

number of slaves, something which smaller farms were unable to do. Furthermore, this study documents a period earlier than his, when slavery started to become established at the Cape.

4.2 Hedonic Slave Characteristics

A secondary research objective of estimating the hedonic model was to understand how Cape buyers valued various characteristics on the market. The discussion that follows provides an overview of the literature on the most important determinants of slave prices, and by implication also the characteristics that were thought to depreciate at fast or slow rates.

Many studies in various regions document a premium paid for male slaves, given the returns to physical strength over their lifetime (Kotlikoff, 1979; Fraginals et al. 1983; Chenny et al. 2003). This attribute took precedence over fertility and the reproduction potential of females. Fraginals et al. (1983) indicate that a childbearing premium that did exist was small, and evidence from the USA reveals that this explains less than 20% of the capital value of female slaves. This is supported by Shell and Rama (2007), who investigate slave prices in the Cape Colony, and conclude that slaves were more valued for their skills than their ability to produce new workers. Fraginals et al. (1983), however, do report some exceptions, which could possibly be ascribed to the type of occupation for which the slaves were required. For example, in urban areas more female slaves were needed for domestic tasks.

In each of the studies referred to, the age-price relationship is concave. The polynomial shape indicates the increments in prices for each additional year, and they rise most rapidly for very young slaves (Kotlikoff, 1979). After the age of 22 years, however, prices started falling. The skill levels of slaves contributed positively to price differentials. For instance, artisans carried higher prices, though other occupations received no premium (Kotlikoff, 1979 and Chenny et al., 2003).

Ethnicity also determined slave prices and was associated with production potential. Malagasy slaves were reportedly less likely to be employed on plantations, as opposed to slaves imported from Mozambique. The former were not as content as the latter, and were more likely to become unruly (Chenny et al., 2003). Slaves from India were

considered small in physique and less suitable to plantation work. They were, therefore, sold at lower prices. Native slaves were often also better priced due to their immunity to the local disease environment and the associated longevity (Fraginals et al. 1983).

5 Data and estimation strategy

Various historical data sources are required to conduct the proposed analysis of prices relative to productivity. Primarily, price data on slaves are necessary to generate a representative index of how buyers valued slaves. In particular, micro-level records over a period of time are required to build a hedonic model. For this purpose, we used the *Changing Hands* database, which contains a full set of sale deeds of slave transfers recorded by the Dutch authorities at auctions and other sales (Shell, 2007)[10]. The database includes slave information (such as the prices at which they were sold, their name, age, gender and origin), as well as the occupations of buyers and sellers that were party to each transaction. The full 4122 records span 1658 to 1768, though only the entries from 1700 to 1725 were used because of the relatively few number of slave sales recorded after that time[11].

The following hedonic models were estimated:

$$log(Slave\ Price_{it}) = \beta_0 + \lambda_t + e_{it} \dots (2)$$

$$log(Slave\ Price_{it} * CPI_{1700}/CPI_t) = \tilde{\beta}_0 + \tilde{\lambda}_t + \tilde{e}_{it} \dots (3)$$

$$log(Slave\ Price_{it} * CPI_{1700}/CPI_t) = \grave{\beta}_0 + x'_{it}\grave{\beta} + \grave{\lambda}_t + \grave{e}_{it} \dots (4)$$

$$i = 1 \dots N_t; t = 1700; \dots; 1725$$

The estimates of the time fixed effects (λ_t) in model (2) are equivalent to the deviation from the base period's mean *log(price)* and represent a price index based simply on the mean of the dependent variable at each point in time. Alternatively, model (3) estimates a time trend based on prices that are deflated by an overall price index to reflect 1700 prices. The reason for this alteration was to remove the effect of overall price inflation from the real trend in slave prices. For this purpose prices were scaled by the economy-

[10] We are indebted to Robert Shell for sharing the databases in a user-friendly format with us.
[11] Though micro-level records over time are contained in this database, they do not constitute a panel dataset. We use pooled cross-section data with various time fixed effects to model the price index.

wide price index developed by Du Plessis and Du Plessis (2012). They construct a consumption basket specific to the Cape Colony, from which it is possible to discern aggregate price trends in the economy over time. Because of the limits of the time coverage of their data, the entire analysis omits all periods before 1700. This date also represents the first significant record of viticulture (and hence the intense use of slaves, as this was the industry in which this type of labour was most successfully implemented) in the production data, so that it is an appropriate starting point for the analysis. Finally, model (4) partials out the hedonic characteristics of slaves. The resultant index, calculated from $\grave{\lambda}_{t,}$ hence represents only the portion of the price that is currently discounted, while the additional coefficients signify the lifetime expected returns ($\acute{\beta}$) to slave characteristics (x_{it})[12].

The purified price index (derived from $\grave{\lambda}_t$) should be compared with the VMP of slaves to assess profitability. To this end, the *Opgaafrollen* (tax returns) of the VOC were used to estimate Cobb-Douglas "total marketable value" (TR) functions – as in equation (5) and their equivalent estimable form (7) – with the objective of finding the Value of the Marginal Product of Slaves (VMP_S) for each farmer. To do this, coefficient estimates on *log(S)* were multiplied by each farmer's average revenue per slave, as shown in equation (6). This dataset consists of detailed micro-level tax records of Cape households, spanning the period 1663 (a decade after the VOC settled at the Cape) until 1773, roughly 30 years before the British assumed rule at the Cape; it is akin to an agricultural census of European settlers – hence, some households appear to have contributed nothing to the economy, as other types of production were not enumerated. These households were omitted from the analysis, as they were likely to be non-farmers: they were concentrated in the district of Cape Town, where other industries dominated. Fourie and Von Fintel (2011) impute incomes to these individuals, with slave numbers as the main predictor. By default, however, such a strategy imposes

[12] The micro records reveal that many sales were conducted as "batch sales". In these cases slaves were clearly not bought on the basis of their personal characteristics, but a discounted price was offered. This does not concur with the notion of value that accrued to buyers, nor with expected returns to characteristics. However, much information on these observations was omitted (such as productive characteristics), so that these peculiar cases were excluded from estimates by default. Furthermore, many characteristics were omitted from the records in later years, so that controlling for the hedonic features dramatically reduced the sample size in that period. Estimating model (2) with the smaller sample introduced sample selection bias for later years. Additionally, estimates of $\grave{\lambda}_t$ were sporadic in later years and imprecisely estimated. For this reason, the study period is truncated to 1725, where these biases are absent or insubstantial.

identical marginal products of slaves to both groups, so that it becomes a superfluous task in this context. Hence, the marginal revenue products were estimated only for the farming sub-population, under the assumption that slaves were concentrated largely in this form of industry. However, to aid comparison the hedonic model also controlled for the occupation of buyers, so that the price indices represent fluctuations for farmers (which formed the reference category). The limited industrial scope of the data presents an important caveat in the interpretation of results: if slaves were actually used in non-agricultural activity, their productivity will be under-estimated using the agricultural data.

The *Opgaafrollen* data outline the size of wine and grain harvests, as well as ownership of cattle, sheep, pigs and weapons, and also the number of slaves and wage labourers employed by each household. Because the records were collected to establish the tithe which farmers had to pay to the VOC, the focus was on production figures, so that information such as land size is a glaring omission. The records were digitized by Dr Hans Heese of the Stellenbosch archive in The Hague, Netherlands. Fourie and Von Fintel (2010; 2011; 2012) provide a fuller description of the dataset. The functional form is as follows:

$$TR = \beta_0 S^{\beta_1} L^{\beta_2} HH^{\beta_3} \prod_{j=1}^{m} K_j^{\beta_{3+j}} \ldots(5)$$

$$VMP_i^S = \frac{\partial TR}{\partial S} = \beta_1 \beta_0 S^{\beta_1 - 1} L^{\beta_2} HH^{\beta_3} \prod_{j=1}^{m} K_j^{\beta_{3+j}} = \beta_1 \frac{TR_i}{S_i} \ldots(6)$$

$$\log(TR_{it}) = \beta_0 + \beta_{t1} \log(S_{it}) + \beta_{t2} \log(L_{it}) + \beta_{t3} \log(HH_{it}) + \sum_{j=1}^{m} \beta_{3+j} logK_{jit} + \lambda_t + \varepsilon_{it} \ldots(7),$$

where *TR* is the total marketable value of farm production, *S* is the total number of slaves owned by a farmer, *L* is the number of European *knechts* employed, *HH* represents the number of household members (which was included for the sake of measuring the productivity of subsistence labour working on their own land)[13]. Each of the K_j items represents other inputs of a capital nature (such as vines, grain that was

[13] By *TR* we mean that even quantities of products that were consumed by the household could potentially have been sold at market prices. The data record the total of home consumption and products that were sold, without distinguishing between them.

sown, and horses) into the production process[14]. Some of these inputs also serve as a proxy for land size, such as the number of vines planted or the number of *muids* of grain sown. In this way, omitted variable bias is minimized, and marginal productivity more accurately estimated. The *i* subscript denotes the farming household, while *t* denotes time. Year fixed effects are included, while household fixed effects are omitted, because this dataset consists of repeated cross-sections. Due to the overlap in the various sources, the *Opgaafrollen* for 1700, 1705, 1709, 1712, 1719 and 1723 were used to estimate VMP of slaves.

The total marketable value of farm production was obtained by multiplying quantities with relevant product prices from the Master of the Orphan Chamber auction rolls (TEPC, 2008)[15]. Annual wine and grain harvests are incorporated into *TR* in this manner, while the treatment of stocks is slightly different. Since not all stock is consumed or sold on the market in a given year, it is assumed that 15% of all animals (sheep, cattle and pigs) were deemed "marketable" in a given year. This figure was also used by Fourie and Von Fintel (2011) to construct total wealth indicators, as suggested by Van Duin and Ross (1987). Horses, in contrast to cattle, are included as a production input, rather than as a part of the marketable value of the farmer's operations. *TR* was scaled by the general price index of Du Plessis and Du Plessis (2012), to aid comparison with the real hedonic price index, that was estimated in 1700 prices.

Equation 7 was first estimated by OLS (Ordinary Least Squares) to obtain the VMP for the average farmer (results are shown in Table 4 in the Appendix), while quantile regressions were implemented along various parts of the total value distribution to investigate the role of scale economies[16]. Additionally, economies of scope were

[14] Because many farmers have zero inputs on some items, the Cobb-Douglas production function would result in sample selection bias once variables are logged. As a result, we impute a "small" value of 0.020 to each zero input, in order to maintain the sample size.

[15] The Orphan Chamber at the Cape was established to administer the estates of individuals who died intestate and left heirs that were either too young or untraceable. While all wills and deaths therefore had to be registered with the Orphan Chamber, the Chamber only inventoried and acted as executor for the estates of free people (Fourie, 2012). In this process of valuating estates, they collected detailed prices of multiple products.

[16] Quantile regressions were estimated in quantile intervals of 5, from 5 to 95. This yields a series of estimates of $\hat{\beta}_1$, weighted at the different values of the *TR* distribution. Farmers were classified into intervals of a five percentile range, centred at the respective quantile regression weights – these observations were associated with respective coefficients from the various regressions. Relevant coefficients were multiplied by each farmer's average revenue with respect to slaves, so that each farmer obtained an individual VMP that hence also reflected their position in the scale distribution. Results for

investigated, by repeating the entire analysis, but by varying the slope coefficients of slavery according to the quintile of a diversity index. The latter is a Herfindahl-Hirschman index that is calculated for each farmer, based on the sum of squared shares in *TR* for each product that was produced. The index is generalized and subtracted from 1, so that 1 represents complete diversity, while 0 represents perfect specialization in one product type.

Furthermore, it was necessary to assess the annual subsistence costs of slaves in profitability calculations. Anecdotal evidence for the annual (continuous) cost of maintaining slaves exists in policy discussion records (Fourie & Von Fintel, 2011). In 1717 it cost about 40 guilders (or 13.33 rixdollars) annually to keep a slave. This cost was inflated to other periods by the price index of Du Plessis & Du Plessis (2012). Compared with the prices and annual productivity estimates, this is a minor cost. However, where relevant, these costs are incorporated into our findings.

Finally, the resulting returns (calculated as the ratio of VMP to the purified price index, net of annual slave subsistence costs) were compared with interest rates to assess how profitable investments were. Interest rates on loans barely varied at the Cape: calculations from the probate inventories yield a consistent figure of six per cent per annum for the period of study (TEPC, 2008), and this same rate has been termed the "cardinal rule of community credit" at the Cape (Dooling, 2007: 188)[x17].

6 Results

6.1 The hedonic price component

Before turning to an analysis of productivity and profitability, this section briefly investigates the hedonic price determinants of slaves at the Cape in Table 1.

[Table 1 here]

selected years are available in Tables 5 to 7, in the Appendix. Additional results are available from the authors on request.

[17] Probate inventories were collected by the Master of the Orphan Chamber (see footnote 15). It was obligatory for every executor of a will to provide the registry with an inventory of the deceased's goods, together with their value.

Firstly, the concavity in age that is found in other studies also appears here. Secondly, no statistically significant male premium is estimated in the data. Figure 2 interrogates these factors. Local polynomial smoothers with 95% confidence bands confirm that across most of the age range, prices offered for male and female slaves were statistically indistinguishable. However, between the ages of 20 and 30, a significant male premium arises (where the confidence bands do not overlap). This segment represents the prime age of slaves, when males (and perhaps not females) could perform physically intense labour, for example, in vineyards. While prices flattened off after the prime age, they did not reflect the strong declines noted in the literature for those younger than 22 years (Kotlikoff, 1979).

[Figure 2 here]

Information on slave origin is highly collinear with variables that control for the origin of the seller. Hence, none of the ethnic effects noted in the literature manifests in these estimates. Interestingly, the coefficient on southern African slaves is negative (although not statistically significant), which goes against all expectations of a native premium.

A clearer view is, however, obtained by considering the origin of sellers[18]. With Batavian sellers (who lived abroad in Indonesia) as a reference category, sellers who were in transit at sea or resident in Table Valley (at the coast of the Cape) received no statistically higher prices. Slaves who were sold by locals in Cape Town were predominantly constituted by shipments from abroad, which they resold to other local households. Hence, prices for this selling region did not differ from slaves sourced abroad. This is confirmed by Shell and Rama's (2007) account of active slave trading and swapping within Cape Town. In all, the premia of other groups relative to this one, suggest that slaves who arrived from abroad did not fetch high prices on the local market. The further the seller's district was from the coast, the greater the premium, with sellers from the broader Cape District obtaining an 18% premium above foreign sellers, 23.3% for those in Drakenstein (the inland region which is known to have been populated by French Huguenots) and 63.3% for those in Hottentots Holland (a

[18] While this does not directly measure a characteristic of slaves as is commonly understood in the hedonic framework, it does proxy for one of these, namely their susceptibility to disease.

mountain range close to the frontier of the day)[19]. This suggests that slaves who were sourced from the interior were more likely to have been born locally, or had served other farmers for long periods and would have acclimatized to the local disease environment.

The occupation of buyers (in other words their position as employees of the VOC, administrators or free farmers) does not directly represent a slave characteristic, but controls for non-market arrangements. This model uses free burghers or farmers as the reference group, so that resultant price indices correspond to this group, and are therefore comparable to the agricultural production data from the *opgaafrollen*. This was also the largest group of buyers in most years of the sample. In particular, VOC employees paid statistically less for slaves than farmers. In contrast, the gentry (as indicated by "Monsieurs") paid a large premium for slaves (not accounted for by other productive characteristics), suggesting that their financial strength allowed them to bid up prices at auctions. We accounted for this factor, so that the willingness to win an auction was not captured in other citizens' price offers.

6.2 Profitability

Figure 3 summarizes the core results of this paper. Three price series were plotted, along with estimates of VMP. These estimates do not yet take the annual costs of maintaining slaves or interest rates into account. The unconditional nominal price series (reflecting only changes in average prices, without accounting for slave characteristics) shows that inflation in slave prices was fairly rapid from 1700 to 1713 (bar for a small temporary decline from 1702 to 1707). Over this period, comparisons with the real price series (using prices scaled by the general price index) emphasize that this trend was not dominated by an overall inflationary trend. In fact, a deflationary overall price trend existed during the eighteenth century (Du Plessis and Du Plessis, 2012).

[Figure 3 here]

[19] Liesbeeck valley, which is near to the coast, is the one region that does not fit this pattern. This was one of the first areas that Van Riebeeck allocated to free farmers to cultivate. However, recorded sales from this region appeared only in 1708, so that this may be an outlying result rather than part of a systematic pattern.

In comparing unconditional real prices with VMP, the following brief discussion takes cognizance that the price series still contains a value component that the buyer anticipated would yield returns in *future*, while VMP represents only the *current* quantity in a given year. Hence it is not yet possible to conclude on profitability. Nevertheless, for the periods where VMP exceeds this price series, it suggests that slaves would have generated enough productivity for their owners to cover costs of acquisition in just one year of work (abstracting from maintenance costs). However, the main purpose of this comparison is to understand whether prices were dominated by cyclical correspondence with productivity, as opposed to changes in the type of slaves bought. The VMP started at a low annual level of less than 50 rixdollars per slave in 1700, before increasing steadily until 1709, as the wine industry – which used slaves most intensively and successfully – became established and changed the production function of the Cape (Fourie & von Fintel, 2012). Initially, unconditional real prices exceeded this value, and their time trend was unrelated to slave productivity. From 1705 to 1719, however, a rough cyclical correspondence arose between real prices and VMP: the initial rise in VMP was followed by a rise in real prices from 1707, to levels not dissimilar from the VMP. VMP was the first to peak in 1709, before experiencing a sustained decline until the end of the period. Prices followed the upward trajectory, before also falling from 1713 until 1719. The period 1713 to 1720 was characterized by severe economic depression that was associated with a smallpox epidemic and several livestock diseases, which led many people to be declared insolvent (Shell, 1997: 117). Time patterns therefore suggest that buyers' willingness to pay for slaves was linked to the realized VMP that they had observed during *previous* harvests. This lagged response is consistent with profit maximisation behaviour.

From 1719 the link between real prices and VMP is broken. After the 1717 policy discussion of the VOC to substitute European immigration with slave importation, prices increased in real terms, which at first glance seems to be demand driven, despite continued decreases in slave productivity. With a declining VMP over this period, it is tempting to conclude that slavery was unprofitable, though it is possible that higher prices reflect slave acquisitions with better characteristics and, hence, a higher probability of longevity and future productivity. Demand for *more* slaves therefore appears to be the unlikely explanation for this rise in prices.

In analysing slave demand, it becomes important to distinguish small from large farmers, based on quintiles of the total value of production[20]. The former group initially relied on Khoikhoi labour, a sub-population that was severely affected by the smallpox epidemic of 1713. Table 2 indicates that the smallest farmers were the most likely to increase their use of slave labour in this period, with a doubling in the average number of slaves from 1712 to 1723 (compared with a stable number for the larger farmers). T-tests confirm that the mean number of slaves increased significantly over this period for the first and third production-size quintiles, but not for the largest farmers. However, production levels did not increase for these groups, with statistically significant decreases in the mean total value of production for quintiles 2 and 3, as shown in Table 2. Hence, rising slave prices could unlikely be attributed to demand for labour that is derived from improved production.

[Table 2 here]

An alternative explanation to demand-driven increases in the real price is that a different type of slave (with better characteristics and expected lifetime production potential) was progressively being bought at the Cape, in response to the high rates of mortality experienced during the 1713 smallpox epidemic. The third price series in Figure 3 controls for the hedonic features of slaves. Firstly, the level of the entire index drops substantially relative to the first two price series, and secondly the trend is subsequently flat over time. Hence, the post-1719 price increase that appears in the other series is primarily the result of the premium that farmers were willing to pay for slaves who would live and work longer. Progressively more slaves were sourced locally so that farmers would face reduced exposure to disease risks experienced by non-native slaves[21].

Once characteristics that are valued over slaves' *lifetimes* are controlled for, the dramatically lower series represents the *current* value that buyers anticipate would cover one period of depreciation, making figures comparable to VMP estimates for one

[20] "Small" is defined by the bottom quintiles of *TR*, rather than land size, due to the absence of indicators for the latter.
[21] In 1700 45% of sellers were situated abroad, while by 1725 this figure had declined to 29.3%.

year[22]. If viewed in this context, slave labour could be profitably expanded by the average farmer throughout the pre-1719 period, when the "purified" price series consistently fell below the VMP realized by the average farmer. Hence excess capacity for using slaves was apparent, before accounting for slave maintenance costs. Figure 5.1 plots the ratio of VMP to the real hedonic series to indicate returns on the investment; the second series adds annual slave maintenance costs to prices to establish net profitability. The horizontal line was plotted at 1.06, the profitability threshold at reigning interest rates of 6%. With and without slave costs, slavery was profitable until 1719 (except in 1702). After this point in time, slavery did not make economic sense for the average farmer.

These results suggest that the average farmer was progressively choosing to tie more capital into more expensive slaves [as is postulated by Fourie (2013)], with the hope that they would deliver higher returns in future, and less risk of mortality (in light of the 1713 smallpox outbreak). Given the dive in profitability post-1719, this prospect did not realize, leading to economic distress and insolvency. This description of slave prices reflects the sentiments of the VOC, whose administration was concerned with the large investments that settlers made in slaves, and whose future returns were not certain (given the large upfront premia that were paid for characteristics, but only realized over the potential lifetime). Furthermore, because slave acquisition was only statistically significant among smaller farmers between 1712 and 1723, the risks were attenuated. The next section therefore explores the different fortunes of small and large farmers.

6.3 Profitability by scale

As the quantile regressions in Tables 5 to 7 in the appendix show, larger farming operations were apparently able to exploit economies of scale to realize higher returns to labour inputs[23]. This was investigated further, by estimating separate VMPs

[22] Unobservables have likely been omitted from the model and are still captured by this series. However, if one assumes that the most important characteristics which buyers based their decisions on would not have been omitted from the sale deeds, then most of the price formation process would have been captured by the included variables, apart from a premium for current productivity (which is what remained after exhaustive controls were introduced). Similarly, unobservables in the calculation of VMP remain, notably land size. However, as noted before, proxies have been introduced to account for this omission.

[23] The coefficients of the inputs in the OLS Cobb-Douglas production function in Table 4 in the appendix, however, do not add up to a value of larger than 1, suggesting that increasing returns to scale did not exist

according to the quintile of the total value of farmers' production, as presented in Figure 4. VMP estimates of the middle quintile most closely correspond with those of the average farmer in Figure 3. Scale effects are clearly present, with the VMP estimates for the top three quintiles substantially above those of the bottom two quintiles, and also exceeding hedonic prices. These farmers employed slaves profitably. However, it appears that the large scale advantage falls dramatically after 1719, when VMP dropped for all groups. Throughout, the smallest farmers did not achieve a VMP that justified the costs indicated by the hedonically adjusted price series, confirming that they did not profitably employ slaves in *agriculture*.

[Figure 4 here]

Figure 5.2 plots ratios of VMP to prices for each scale quintile, without taking annual slave costs into consideration, while Figure 5.3 adds these to prices. The observations from the previous analysis are confirmed, with slavery supposedly not being profitable for first quintile farmers, but being marginally so for second quintile farmers. Additionally, a downward turn in high returns for other groups in 1709 to virtually zero in the post-1719 period occurred. Once taking slave costs into account, profitability remains for the top three quintiles up to 1719, while the second quintile slips into a region of zero to negative profits across the entire time span.

[Figure 5 here]

Together, these observations suggest that the smallest 20% of farmers invested unprofitably in slavery, and by some criteria the same is true for the smallest 40% of farmers. However, slaves were among the first "products" that even the least wealthy farmers acquired (Fourie, 2013), which is supported by our analysis in Table 2. Small farmers potentially interpreted the high slave populations of the rich as the secret to their success, and invested in more expensive slaves to emulate their profitability. An alternative explanation is that not only did small farmers utilize slaves in agriculture (which is the only type of output recorded in our data), but also that they were valuable

across *all* inputs. However, the results of quantile regressions in Tables 5 to 7 in the appendix show that farmers with a larger output reaped higher benefits from *slaves*. Furthermore, these functions do not control for land size (which are not available in the current data), so that this omitted factor would potentially allow us to conclude overall increasing returns to scale.

in other types of production. Notably, small farmers may also have specialized in investing in slaves for resale on the active market rather than for direct agricultural production, which also occurred in the relatively low agricultural production regions in the USA (Shell and Rama, 2007, Conrad & Meyer, 1958). The geographic concentration of slaves in the Colony at the beginning of the eighteenth century was highest in the Cape District, which also had a lower concentration of farming; this was followed by Stellenbosch, which was a predominantly wine-producing region and Drakenstein, which specialized in wheat cultivation (Worden, 1985). "Small farmers" were therefore likely involved in other industries, and slaves would potentially have been profitably employed domestically or in other non-agricultural activities. Our conjecture that small farmers were closer to urban centres is strengthened by the existence of market gardens. They produced fresh produce such as vegetables and therefore had to be located close to the port and town (Shell, 1997). Furthermore, the slave economy was urban-natured: most slaves were based in the Cape District during the period 1705 to 1731 (Worden, 1985). In addition, approximately 47.6% of all slave owners lived within 3 hours of the village centre (Shell, 1997). Our data also indicate that 46.3% of quintile 1 farmers lived in Cape Town, the most urbanized centre of the Colony. Quintile 2 to 4 farmers were concentrated in Drakenstein (between 45% and 60%), which at that stage was at the frontier of the Colony.

Additional analysis of Table 2 explores how the production of small farmers differed from larger farmers. The poorest quintile of farmers consistently derived large proportions of their *agricultural* production value from wine, with the share often in excess of 10 or 15%. This pattern is not seen in any of the other quintiles. Paradoxically, this is also the product that has been attributed to the rise of an elite, and is associated strongly with slave labour (Fourie and Von Fintel, 2012, Giliomee, 2004). However, the 5th quintile achieved absolute wine yields that were consistently more than triple those of the first quintile, with a persistently high factor difference in the average number of slaves employed. These figures point to the fact that larger farmers did not necessarily specialize their production, but that the smallest farmers tended to do so. However, slave to wine ratios were highest in this poorest group and increased over time, indicating that they were increasingly disadvantaged by their small scale, despite their attempts to specialize. The largest farmers had lower slave to wine ratios, despite this product constituting a smaller share of total production. One explanation for this

pattern could be that small farmers also hoped to break into the lucrative wine industry, but other constraints limited them to do so. Alternatively, small farmers produced small volumes of wine for private consumption and earned their keep with non-agricultural activities.

The third and fourth quintiles were, however, even more successful than the largest farmers at producing wine with slave labour, as their slave to wine ratios were even lower. This is can also be seen in Figure 4, where the VMP of the fourth quintile exceeds that of the fifth in many instances. The rise of this group after 1705 also reflects the increased availability of land following the VOCs ban on company officials from farming (Guelke and Shell, 1983); these officials were initially able to exploit their favourable positions to constitute a distinct elite. However, with freer access to cheaper land, middle groups also appear to have been able to realize higher profits from slaves, suggesting potential complementarity of these capital inputs. Again, the lack of data on land does not allow us to test this assertion.

In addition to the results for wine, Table 2 also shows the share of grain in total value of production. In contrast to wine, small farmers (in quintiles 1 and 2) had relatively less success with producing grain; this share is small throughout the period under scrutiny. Small farmers were therefore not likely to have produced for the export market, as volumes of various products were small.

A final important result in Table 2 is the proportion of farmers producing *both* wine and grain. Almost no farmers in the lowest quintile produced both agricultural products. In contrast, the majority of farmers (more than 78% in all the years under investigation) in quintile 5 produced both wine and grain. Small farms also had persistently lower crop diversity indices. Across all years the smallest farmers were most likely to specialize in few products. By contrast, the largest farmers hardly registered diversity scores below 0.5. Due to the seasonality of the demand for labour, farmers reduced the gap between work and production time by engaging in mixed farming, a strategy that was available to large landowners who could afford a large number of slaves (Green, 2013). These results, combined with the relative shares of the other two main farming activities (wine and livestock farming), suggests that small farmers faced constraints that limited their ability to diversify production and use inputs (such as slaves) in multiple

production processes. In contrast, quintiles 3 to 5 were able to increase product diversity by statistically significant values. Again, the smallest farmers potentially *chose* not to diversify, limiting themselves to small volumes of home consumption products. Distinguishing between these explanations requires supplementary data.

A possible explanation for the lack of crop diversity among small farmers may be linked to the extent to which they acquired capital products, such as ploughs, oxen and wagons. Turning to supplementary data from the probate inventories, Table 3 shows the mean number of such capital goods over the period (1673 to 1730) for different slave categories within which our quintiles are subsumed[24;25]. Small farmers (quintiles 1 and 2, which are subsumed in slave category 1 with less than 3 slaves) possessed fewer capital goods, compared with farmers in quintile 5 (slave category 3 with more than 6 slaves); the former category had a mean number of ploughs of 0.25, compared with 1.5 for quintile 5. One possible explanation is that small farmers were *unable* to purchase capital inputs (such as ploughs and wagons), but attempted to emulate the success of large farmers by expanding their slave labour holdings to the large degree that they did. Land and slaves accounted for approximately 70% of capital investment by most farmers; the remainder consisted of capital equipment (e.g. ploughs and wagons) and livestock (Worden, 1985). Slaves could therefore have been acquired with the intention to substitute for a lack of other physical capital. However, where farmers possessed both slaves and physical capital, these inputs were complementary and augmented output. Slaves were therefore profitable in agriculture when farmers also acquired other forms of capital. Another plausible explanation is quite simply that small farmers did not invest in other capital goods because agriculture was not their main business: rather, slaves were bought by "farmers" that were concentrated in urban Cape Town and also involved in other industry. If this were the case, it would be wrong to conclude that slavery was unprofitable for small farmers, but rather that they were employed in unmeasured, non-agricultural activity.

[24] Probate inventories are lists of assets owned by deceased individuals or households. They included all deceased settlers, who were not necessarily farmers. However, since the type of capital goods we analysed would most probably have been used by farmers, we assumed this would not affect our analysis.
[25] Slave categories, in line with figures for each *TR* quintile from Table 2, were created in the Probate Inventories to proxy for farm size. There is no other way to match wealth between these records and the *Opgaafrollen*.

Additional analysis in Tables 5 to 7 in the appendix assesses more formally whether the scope of agricultural production plays a role in profitability. One constant factor across time in these results, is that even when the smallest farmers attempted to diversify, they did not realize higher productivity. Their small scale limited them, so that employing slaves was not economically viable, regardless of the scope of their production. Medium-sized producers, in contrast, became progressively wealthier over time by using slaves to diversify their crop and stock types. They resembled the pattern for the largest farmers more closely, who could hedge against crop failure and use labour year round in mixed farming operations. The progress of middle quintile farmers is consistent with the notion that they faced capital constraints. However, as exclusive market power was removed from the VOC elite, allowing other farmers access to compete in the market for land for the first time, medium-sized producers were allowed to become both larger and more diverse in their production. As a result, slaves could also be employed at similarly high rates of return to the largest farmers, especially quintile 4 farmers. Overcoming capital constraints therefore did play an important role in achieving profitability from slaves. However, this argument is verified for medium-sized farmers and not the smallest, so that the alternative hypothesis that "small farmers" were actually engaged in other industry remains plausible.

[Table 3 here]

7 Conclusions

This paper set out to assess whether slavery at the Cape was a profitable investment for local settlers, by comparing prices with VMP, slave maintenance costs and interest rates. Shortly after the turn of the eighteenth century, the VOC policy council debated whether it would be more economically viable to encourage European settlement or the importation of slaves to satisfy the labour demands of the expanding economy. Due to widespread settler poverty and the perceived low costs of slaves, the decision was made to substitute paid European labour with slaves. However, Chavonnes warned then already that this was dead money, and this was reflected in the VOC's concern at the large amounts of capital that settlers had invested in slaves. Nevertheless, it is clear that some (perhaps elite) farmers' success hinged on the use of slaves, particularly on large

farms. This finding is in accordance with, among others, the work done on American slavery by Fogel and Engerman (1974), Vedder and Stockdale (1975) and also by Ward (1978) on slavery in the West Indies. Our results coincide with the findings of Worden (1985) on the returns to slaves in the Cape Colony, although his analysis was for a later period in the eighteenth century, and used aggregate data rather than statistical estimation using micro records.

A simple aggregate price series would convince us that the shift in demand towards slaves drove the inflation in sale prices between 1705 and 1715. However, other factors were also at play. The smallpox epidemic of 1713 (which depleted the source of Khoikhoi labour) served as another shock that potentially raised the demand and prices of slaves in this period. Prices continued to rise steadily over time, suggesting that these isolated shocks could not explain the steady inflation in buyers' willingness to pay for slaves. The hedonic model turns to supply-side issues, and in particular to slave characteristics as determinants of slave price inflation. The resultant "purified" index shows that prices were fairly constant, indicating that buyers paid primarily for long-term returns on slave characteristics. Farmers were willing to buy slaves with better characteristics (proxying for higher life expectancy) following the smallpox epidemic of 1713, which brought about the death of many at the Cape.

However, expansion in slavery occurred fastest within the group of small farmers. This potentially supports the VOC's concerns about over-investment in this type of labour. The analysis shows that regardless of period, or whether specialization was pursued, this group did not profitably employ slaves in *agriculture*, though other unmeasured benefits may have accrued by using slaves in other activities, or in resale transactions.

Medium to large farmers could use their scale advantages to branch out into diverse crops. The literature indicates that farmers benefitted from using the same slaves by cultivating and harvesting various crops at different times of year. Slavery, however, appeared to be an expensive cost to bear for small farmers, and they did not recover this in agriculture: either they "over-invested" in slave capital in the hope of yielding returns that only diversification could offer them, or they successfully obtained profits from slaves in home production or in other industries. The latter explanation is more

likely, as small farmers would have sold off slaves if they were unprofitable (as our estimates show for an entire 25-year horizon).

Some evidence is also presented here to suggest that small farmers were less likely to acquire *alternative* capital equipment (which the rich did possess); these "more expensive" investments would have yielded higher agricultural returns than expanding their slave numbers. In contrast, richer farmers benefitted greatly from the exploitation of this source of labour due to the complementary capital equipment that they could afford. The removal of exclusive market power for land from 1705 allowed medium sized farmers to overcome some of these capital constraints, increase their crop diversity and returns to slavery rose rapidly for this group. The smallest farmers, however, never realized these benefits, either because they could not overcome other capital constraints, or because they never intended to focus primarly on agricultural production. Slaves could nevertheless have been profitably employed by these smallest farmers in unmeasured, non-agricultural activity.

The conflicting reports of the Cape governors Chavonnes and Janssens were likely both to be true at the same time. However, while Chavonnes was concerned with the impoverishment of the bottom of the *agricultural* wealth distribution as a result of slavery, Janssens' remarks demonstrate that slavery at the Cape was indeed profitable for farmers who could afford *many* slaves.

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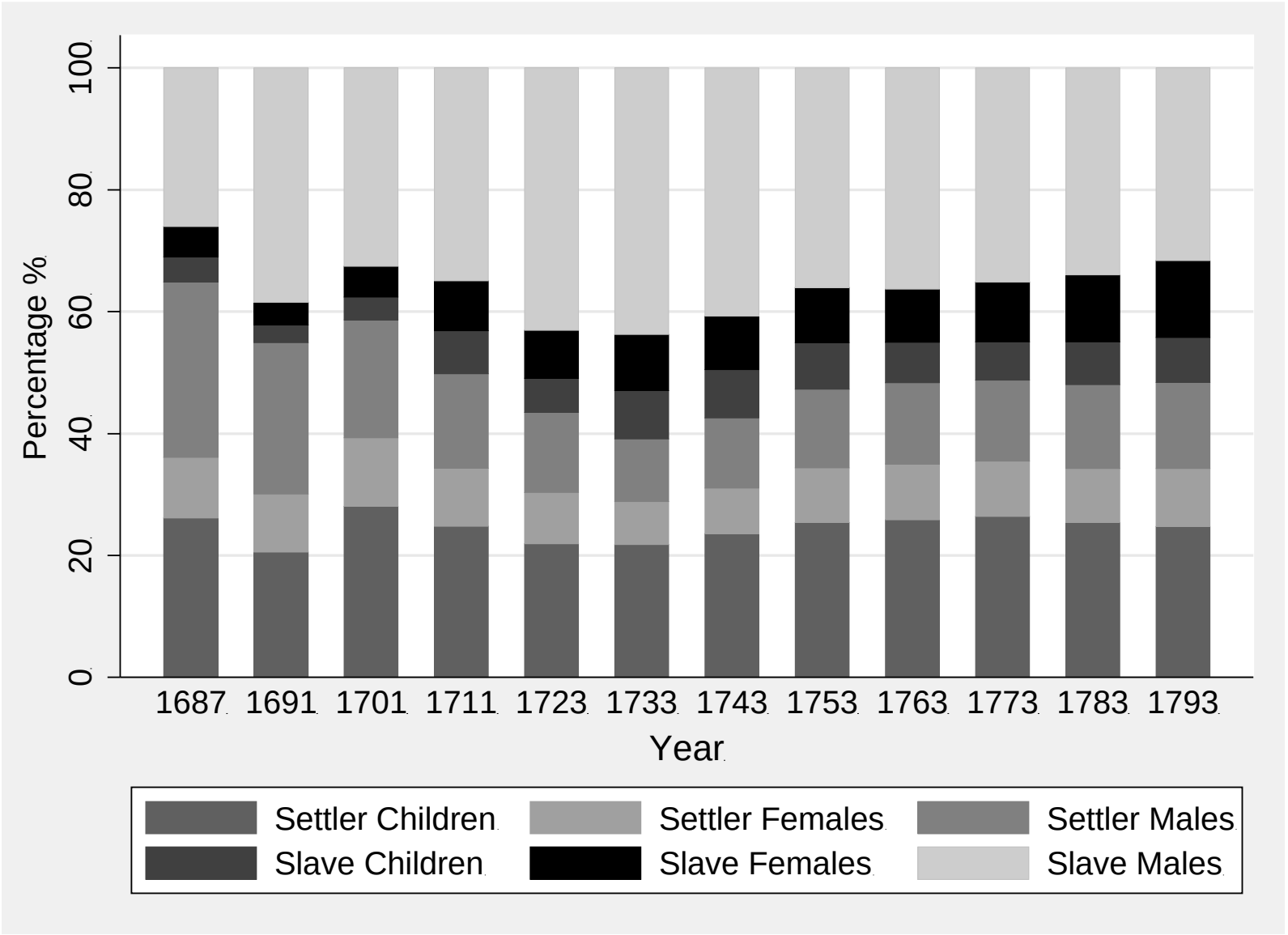

Figure 1 Changing Population Composition. Source: calculations based on Worden (1985:53)

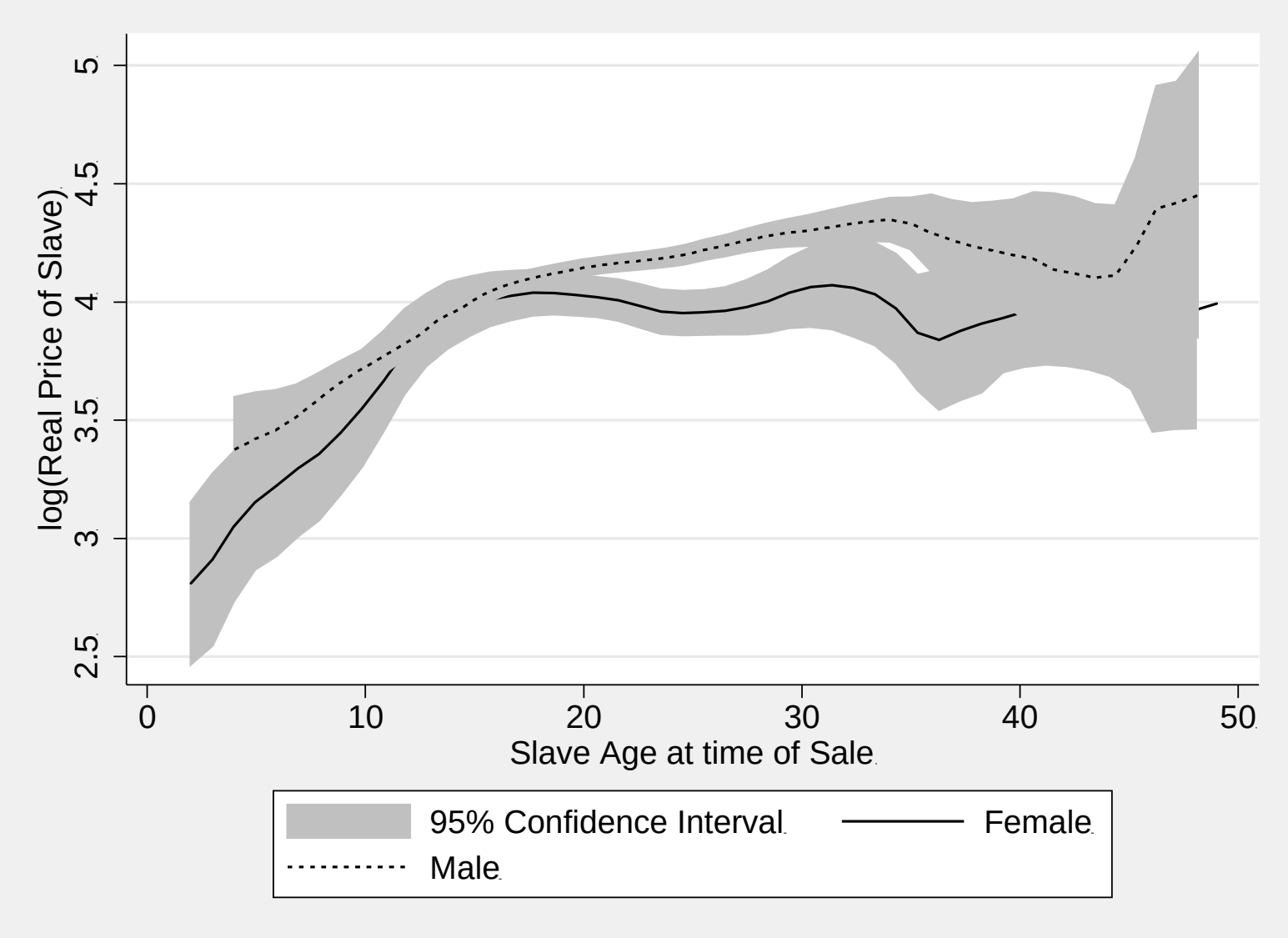

Figure 2 Price Returns to Age and Gender (Source: Own calculations)

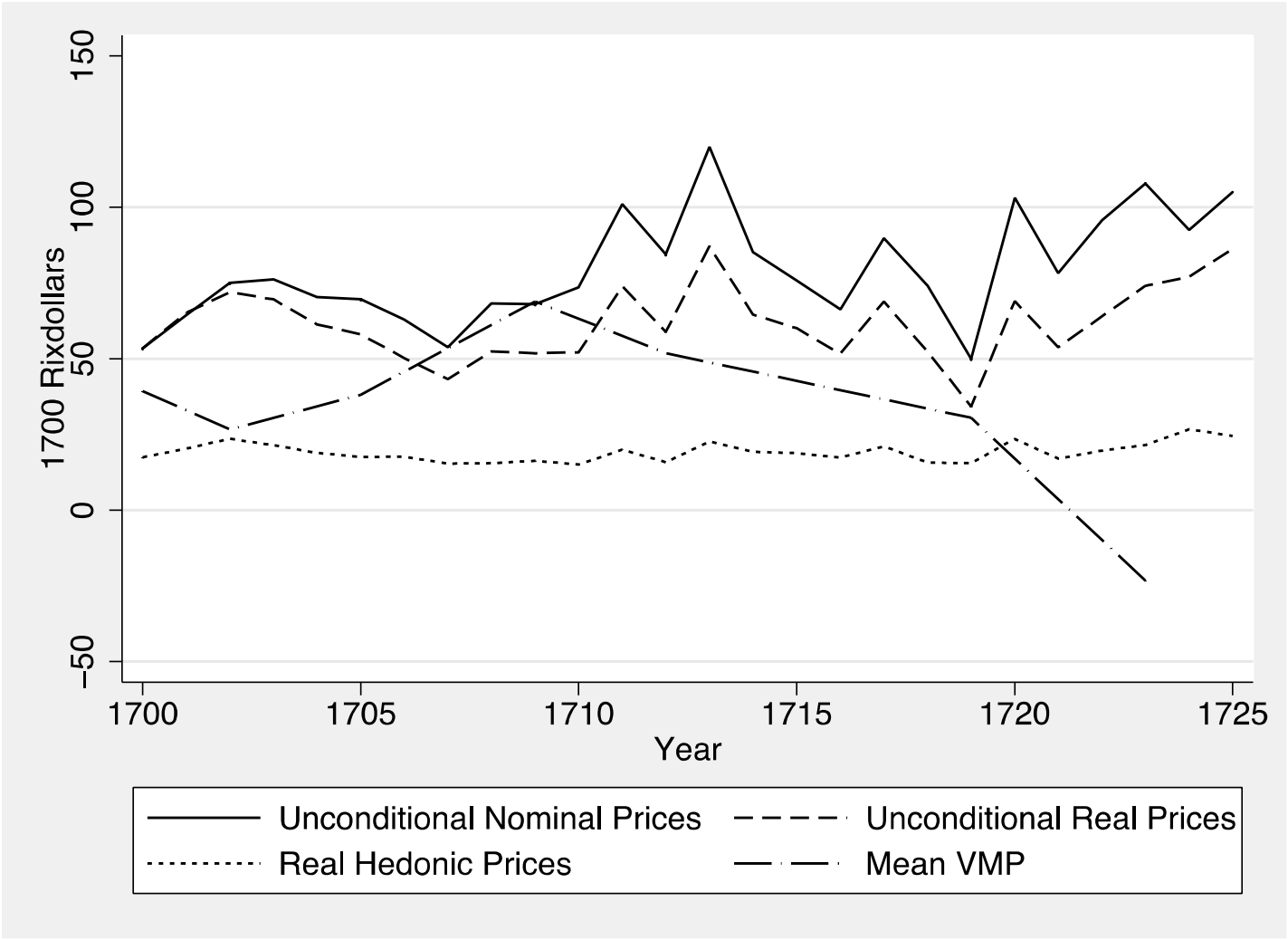

Figure 3 Prices and Value of Marginal Productivity

NOTES: Own calculations from *opgaafrollen* and *Changing Hands* databases. VMP is the average VMP of all farmers in a given year, derived from the Cobb-Douglas function without heterogeneous slopes (see Table 4 in the appendix). Unconditional price series' are derived from time dummies of slave price models without controls. The Hedonic series is derived from a similar model, after the hedonic characteristics are controlled for.

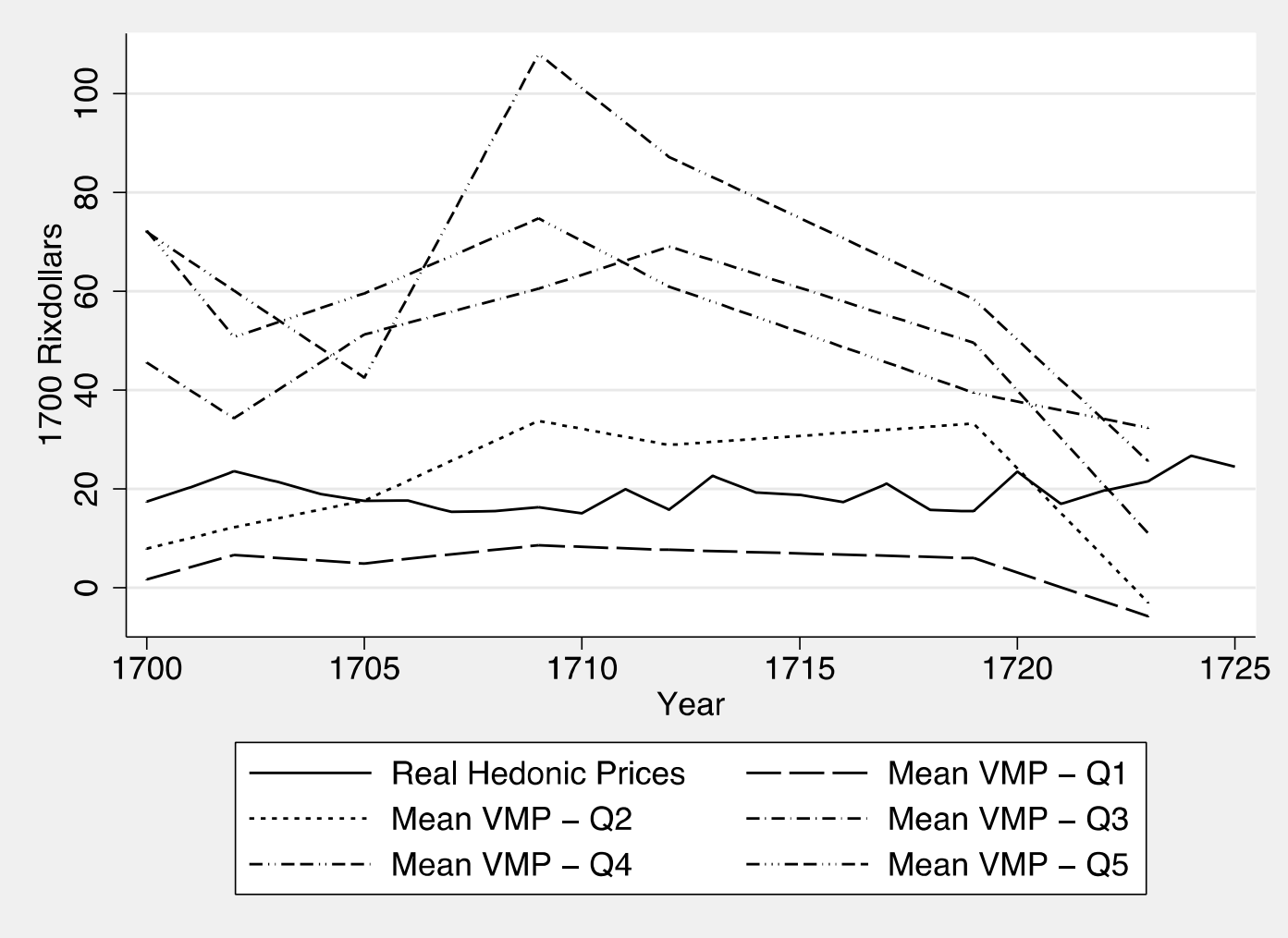

Figure 4 Prices and Value of Marginal Productivity – by scale

NOTES: Own calculations from *opgaafrollen* and *Changing Hands* databases. VMP is the average VMP of all farmers within their respective *TR* quintiles in a given year. These are derived from the Cobb-Douglas functions estimated by quantile regressions without heterogenous slopes (see Tables 4-6). Quantile regressions weighted in intervals of 5 from 5 to 90 were estimated. Coefficients in the VMP calculations are assigned to observations in a 5 percentile interval centred about the quantile weight. Unconditional price series' are derived from time dummies of slave price models without controls. The Hedonic series is derived from a similar model, after the hedonic characteristics are controlled for.

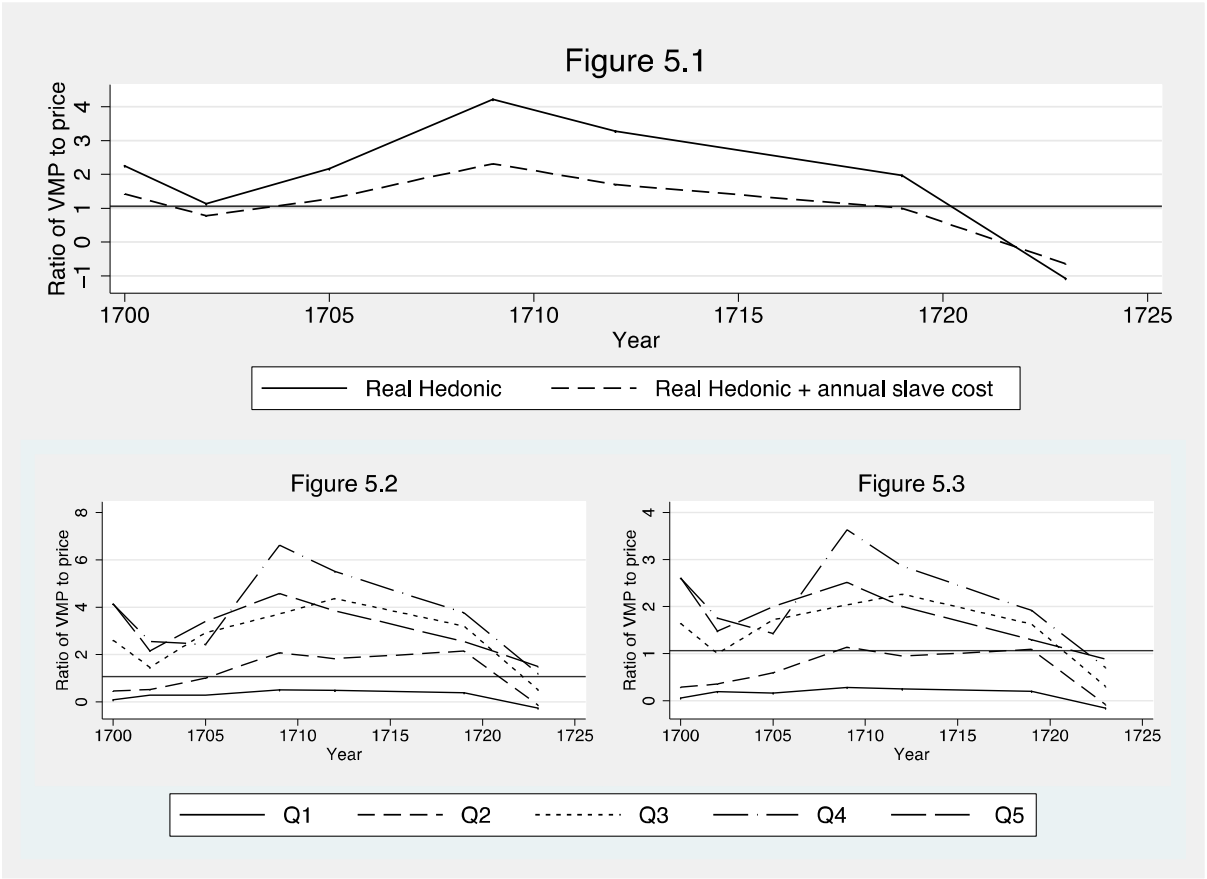

Figure 5 Ratio of Value of Marginal Productivity to Hedonic Prices

NOTES: Own calculations from *opgaafrollen* and *Changing Hands* databases. All series are ratios of VMP to Prices. A horizontal line of 1.06 indicates the expected return at a prevailing 6% interest rate. In Figure 5.1. VMP is the average VMP of all farmers in a given year, derived from the Cobb-Douglas function without heterogeneous slopes (see Table 4 in the appendix). The Hedonic series is derived from controls for slave characteristics. The second series adds annual slave costs to prices. In Figures 5.2 and 5.3 VMP is the average VMP of all farmers within their respective *TR* quintiles in a given year. These are derived from the Cobb-Douglas functions estimated by quantile regressions without heterogeneous slopes (see Tables 4-6). Quantile regressions weighted in intervals of 5 from 5 to 90 were estimated. Coefficients in the VMP calculations are assigned to observations in a 5 percentile interval centred about the quantile weight. Unconditional price series' are derived from time dummies of slave price models without controls. The Hedonic series is derived from a similar model, after the hedonic characteristics are controlled for. Figure 5.3. adds annual slave costs to prices.

Table 1 OLS Hedonic Slave Price Function (Source: Own Calculations from Slave Sale Deeds)

	log(Real Prices)
Male	-0.027
Age	0.076***
Male x Age	0.013
Age Squared	-0.001***
Male x Age Squared	0.000
Origin: East Africa	*Reference*
Origin: Indonesia	0.129
Origin: Ceylon & India	0.111
Origin: Madagascar & Mauritius	0.002
Origin: Southern Africa	-0.030
Origin: West Africa	0.270
Seller Location: Batavia	*Reference*
Seller Location: Cape district	0.180**
Seller Location: Drakenstein	0.233**
Seller Location: Hottentots Holland	0.633***
Seller Location: Liesbeeck valley	-0.407***
Seller Location: Stellenbosch district	0.205**
Seller Location: Table valley	0.080
Seller Location: Transit-at sea	-0.030
Buyer Status: Farmer	*Reference*
Buyer Satus: Councillor	-0.029
Buyer Status: Justice	0.033
Buyer Status: Magistrate	-0.017
Buyer Status: Monsieur	0.230*
Buyer Status: VOC employee	-0.151***
Buyer Status: free black	-0.065
Buyer Status: Time expired convict	0.15
Constant	2.859***
Time Fixed Effects	YES
N	641
R-Squared	0.452

Table 2 Mean Share of Agricultural produce and livestock in Total Value; Crop diversity measure and mean number of Slaves

Year	Variable	Total Value Quintile					Variable	Total Value Quintile				
		1	2	3	4	5		1	2	3	4	5
1700	Total value (rixdollars)	49.083	192.477	412.905	802.894	2276.112	Diversity	0.121	0.495	0.683	0.770	0.832
		(3.557)	(8.830)	(12.580)	(27.361)	(140.784)		(0.034)	(0.037)	(0.027)	(0.021)	(0.010)
	Wine (leaguers)	1.021	2.717	3.348	5.391	12.196	Share of wine in total value	0.260	0.205	0.101	0.086	0.071
		(0.259)	(0.461)	(0.443)	(0.572)	(1.485)		(0.060)	(0.040)	(0.013)	(0.009)	(0.008)
	Grain reaped (muids)	0.106	5.348	16.783	35.587	92.848	Share of grain in total value	0.021	0.350	0.574	0.630	0.577
		(0.076)	(0.854)	(1.094)	(1.727)	(7.246)		(0.015)	(0.052)	(0.032)	(0.021)	(0.018)
	Cattle (head)	7.021	15.500	24.174	37.174	122.630	Share of animals in total value	0.720	0.444	0.324	0.283	0.351
		(0.788)	(1.868)	(1.982)	(2.708)	(9.902)		(0.060)	(0.054)	(0.028)	(0.018)	(0.019)
	Sheep (head)	11.064	41.522	75.109	197.717	809.783	Total slaves	0.830	1.000	1.152	2.543	11.478
		(6.024)	(16.503)	(16.979)	(29.859)	(114.889)		(0.232)	(0.273)	(0.382)	(0.500)	(1.305)
	Pigs (head)	0.000	0.326	0.413	1.543	5.826	Proportion producing wine & grain	0.000	0.391	0.696	0.913	0.870
		(0.000)	(0.194)	(0.144)	(0.434)	(1.150)		(0.000)	(0.072)	(0.068)	(0.042)	(0.050)
1702	Total value (rixdollars)	42.412	155.653	398.075	836.435	2270.967	Diversity	0.098	0.273	0.646	0.737	0.774
		(2.990)	(6.920)	(13.018)	(23.693)	(162.237)		(0.028)	(0.040)	(0.031)	(0.024)	(0.017)
	Wine (leaguers)	0.961	1.000	3.627	3.196	10.340	Share of wine in total value	0.230	0.074	0.102	0.042	0.053
		(0.238)	(0.263)	(0.494)	(0.474)	(1.276)		(0.055)	(0.023)	(0.014)	(0.006)	(0.006)
	Grain reaped (muids)	0.000	2.078	11.510	31.765	73.280	Share of grain in total value	0.000	0.176	0.395	0.544	0.479
		(0.000)	(0.492)	(1.235)	(1.795)	(5.434)		(0.000)	(0.043)	(0.038)	(0.027)	(0.025)
	Cattle (head)	4.843	18.804	27.745	44.608	144.780	Share of animals in total value	0.770	0.750	0.503	0.414	0.468
		(0.644)	(1.567)	(2.106)	(3.350)	(13.972)		(0.055)	(0.048)	(0.038)	(0.026)	(0.025)
	Sheep (head)	13.980	35.922	119.216	287.118	886.600	Total slaves	0.902	0.902	1.333	2.431	9.820
		(5.270)	(11.119)	(25.409)	(37.398)	(155.588)		(0.231)	(0.344)	(0.362)	(0.457)	(1.177)
	Pigs (head)	0.706	0.196	0.431	1.412	4.640	Proportion producing wine & grain	0.000	0.176	0.569	0.667	0.860
		(0.245)	(0.158)	(0.224)	(0.429)	(0.810)		(0.0000	(0.053)	(0.069)	(0.066)	(0.049)

Year	Variable	Total Value Quintile					Variable	Total Value Quintile				
		1	2	3	4	5		1	2	3	4	5
1705	Total value (rixdollars)	75.672	228.693	414.032	763.293	1810.369	Diversity	0.197	0.521	0.684	0.730	0.813
		(5.878)	(7.425)	(9.522)	(24.799)	(184.969)		(0.044)	(0.042)	(0.029)	(0.030)	(0.014)
	Wine (leaguers)	1.841	2.977	2.864	4.614	10.698	Share of wine in total value	0.266	0.103	0.054	0.050	0.049
		(0.349)	(0.589)	(0.390)	(0.684)	(1.611)		(0.057)	(0.021)	(0.007)	(0.007)	(0.006)
	Grain reaped (muids)	0.841	7.091	18.955	36.886	66.837	Share of grain in total value	0.103	0.373	0.611	0.633	0.548
		(0.318)	(1.082)	(1.094)	(2.138)	(3.661)		(0.037)	(0.056)	(0.034)	(0.029)	(0.027)
	Cattle (head)	4.864	8.773	8.886	16.000	40.256	Share of animals in total value	0.631	0.524	0.335	0.316	0.403
		(0.717)	(1.134)	(0.535)	(0.999)	(5.940)		(0.063)	(0.055)	(0.034)	(0.027)	(0.027)
	Sheep (head)	25.296	88.182	140.909	229.091	1056.980	Total slaves	1.455	1.886	1.159	2.909	10.744
		(10.011)	(19.990)	(27.553)	(33.883)	(259.390)		(0.354)	(0.510)	(0.245)	(0.471)	(1.536)
	Pigs (head)	0.091	0.091	1.636	1.591	2.907	Proportion producing wine & grain	0.136	0.318	0.636	0.705	0.907
		(0.091)	(0.091)	(0.832)	(0.638)	(0.893)		(0.051)	(0.070)	(0.073)	(0.069)	(0.044)
1709	Total value (rixdollars)	105.626	400.671	897.857	1775.631	5723.440	Diversity	0.103	0.510	0.626	0.634	0.669
		(6.879)	(12.816)	(24.853)	(43.439)	(442.545)		(0.028)	(0.031)	(0.022)	(0.015)	(0.015)
	Wine (leaguers)	0.732	3.018	3.321	3.304	10.964	Share of wine in total value	0.146	0.083	0.044	0.020	0.020
		(0.248)	(0.650)	(0.946)	(0.530)	(1.922)		(0.043)	(0.018)	(0.013)	(0.003)	(0.002)
	Grain reaped (muids)	0.518	8.161	34.321	80.000	250.518	Share of grain in total value	0.048	0.242	0.464	0.551	0.546
		(0.266)	(1.298)	(2.540)	(3.997)	(20.357)		(0.025)	(0.038)	(0.031)	(0.025)	(0.021)
	Cattle (head)	9.018	24.161	40.732	71.411	244.464	Share of animals in total value	0.807	0.675	0.491	0.429	0.434
		(1.028)	(1.894)	(2.951)	(4.522)	(33.779)		(0.048)	(0.040)	(0.028)	(0.025)	(0.021)
	Sheep (head)	45.536	167.500	265.714	441.071	1373.790	Total slaves	1.536	2.000	2.393	4.375	16.714
		(13.258)	(28.086)	(31.244)	(37.756)	(186.855)		(0.355)	(0.503)	(0.372)	(0.534)	(1.604)
	Pigs (head)	0.000	0.339	0.161	0.250	2.446	Proportion producing wine & grain	0.036	0.357	0.589	0.607	0.875
		(0.000)	(0.149)	(0.087)	(0.106)	(0.695)		(0.025)	(0.064)	(0.066)	(0.065)	(0.044)

Year	Variable	Total Value Quintile					Variable	Total Value Quintile				
		1	2	3	4	5		1	2	3	4	5
1712	Total value (rixdollars)	74.622	289.378	659.272	1211.032	3085.915	Diversity	0.104	0.449	0.656	0.724	0.759
		(4.038)	(11.765)	(16.591)	(32.939)	(160.271)		(0.028)	(0.034)	(0.019)	(0.014)	(0.011)
	Wine (leaguers)	0.733	1.534	2.915	4.661	8.288	Share of wine in total value	0.172	0.105	0.082	0.069	0.045
		(0.199)	(0.400)	(0.697)	(0.865)	(1.294)		(0.045)	(0.028)	(0.020)	(0.013)	(0.006)
	Grain reaped (muids)	0.633	7.845	26.831	54.949	153.237	Share of grain in total value	0.069	0.237	0.377	0.430	0.461
		(0.266)	(1.318)	(2.496)	(3.582)	(12.229)		(0.029)	(0.038)	(0.032)	(0.026)	(0.020)
	Cattle (head)	6.133	20.293	36.695	65.983	163.966	Share of animals in total value	0.759	0.658	0.542	0.501	0.494
		(0.768)	(1.887)	(2.279)	(3.528)	(9.666)		(0.053)	(0.042)	(0.030)	(0.022)	(0.020)
	Sheep (head)	38.167	137.517	280.339	438.305	1035.170	Total slaves	1.483	2.103	2.305	4.966	17.729
		(10.389)	(24.975)	(33.138)	(28.544)	(82.108)		(0.336)	(0.477)	(0.406)	(0.637)	(1.571)
	Pigs (head)	0.283	0.138	0.390	0.932	2.237	Proportion producing wine & grain	0.067	0.190	0.424	0.559	0.780
		(0.147)	(0.090)	(0.187)	(0.348)	(0.739)		(0.032)	(0.051)	(0.064)	(0.065)	(0.054)
1719	Total value (rixdollars)	58.660	218.031	445.103	899.324	2218.263	Diversity	0.125	0.390	0.537	0.657	0.701
		(4.742)	(6.433)	(12.459)	(23.221)	(134.206)		(0.029)	(0.036)	(0.027)	(0.018)	(0.016)
	Wine (leaguers)	0.894	0.938	1.712	3.909	9.891	Share of wine in total value	0.277	0.059	0.052	0.061	0.061
		(0.193)	(0.198)	(0.357)	(0.793)	(1.213)		(0.050)	(0.012)	(0.011)	(0.012)	(0.008)
	Grain reaped (muids)	1.333	9.415	19.591	39.530	133.422	Share of grain in total value	0.102	0.225	0.241	0.241	0.328
		(0.457)	(1.559)	(2.686)	(4.094)	(12.775)		(0.033)	(0.036)	(0.033)	(0.025)	(0.023)
	Cattle (head)	3.227	17.139	31.106	59.015	130.516	Share of animals in total value	0.621	0.716	0.708	0.698	0.611
		(0.541)	(1.120)	(1.861)	(3.068)	(9.921)		(0.057)	(0.037)	(0.034)	(0.026)	(0.023)
	Sheep (head)	21.515	27.862	117.818	284.470	554.594	Total slaves	2.561	2.477	3.848	6.924	17.031
		(6.680)	(7.054)	(14.802)	(19.814)	(80.881)		(0.556)	(0.629)	(0.604)	(0.903)	(1.404)
	Pigs (head)	1.470	1.077	1.652	3.530	8.500	Proportion producing wine & grain	0.091	0.246	0.364	0.500	0.781
		(0.365)	(0.296)	(0.376)	(0.686)	(1.271)		(0.035)	(0.053)	(0.059)	(0.062)	(0.052)

Year	Variable	Total Value Quintile 1	2	3	4	5	Variable	Total Value Quintile 1	2	3	4	5
1723	Total value (rixdollars)	76.013	252.344***	483.040***	949.326***	2697.297*	Diversity	0.124	0.396	0.577**	0.674**	0.701***
		(5.866)	(5.368)	(11.664)	(23.983)	(184.635)		(0.024)	(0.033)	(0.027)	(0.016)	(0.018)
	Wine (leaguers)	0.237*	1.329	2.205	3.233*	11.027*	Share of wine in total value	0.071**	0.072	0.060	0.046*	0.052
		(0.075)	(0.297)	(0.354)	(0.618)	(1.496)		(0.025)	(0.016)	(0.010)	(0.009)	(0.006)
	Grain reaped (muids)	0.421	4.029***	15.836***	43.288**	179.575	Share of grain in total value	0.031	0.091***	0.186***	0.268***	0.375***
		(0.177)	(0.873)	(1.942)	(3.980)	(18.986)		(0.014)	(0.019)	(0.022)	(0.022)	(0.023)
	Cattle (head)	7.724*	23.643*	37.712	63.425	152.945	Share of animals in total value	0.898**	0.837***	0.754***	0.686***	0.573***
		(0.785)	(1.108)	(1.557)	(2.827)	(11.089)		(0.030)	(0.028)	(0.026)	(0.024)	(0.023)
	Sheep (head)	20.737*	62.129***	145.260***	334.699***	640.233***	Total slaves	3.329***	1.957	4.274**	4.795	17.753
		(6.326)	(10.058)	(14.088)	(25.198)	(49.289)		(0.519)	(0.531)	(0.878)	(0.494)	(1.657)
	Pigs (head)	1.132***	0.643***	1.507**	2.164***	9.822***	Proportion producing wine & grain	0.039	0.200	0.384	0.425*	0.822
		(0.253)	(0.164)	(0.456)	(0.376)	(1.810)		(0.022)	(0.048)	(0.057)	(0.058)	(0.045)

NOTES: Own calculations from *Opgaafrollen.* Means, with standard errors of means in parentheses. For 1723 one-sided t tests were conducted to establish whether increases or decreases were statistically significant from 1712 to 1723 *Increase/Decrease in mean between 1712 and 1723 statistically significant at 10% **Increase/Decrease in mean between 1712 and 1723 statistically significant at 5% ***Increase/Decrease in mean between 1712 and 1723 statistically significant at 1%

Table 3 Mean Capital Goods by Slave Category for the period 1673 to 1730

Slave category	Oxen	Horses	Brandy kettles	Wagons	Ploughs
Less than 3 slaves	13.273	1.053	0.027	0.345	0.248
(TR Quintiles 1 and 2)	(1.574)	(0.125)	(0.010)	(0.039)	(0.030)
3 to 6 slaves	39.387	2.757	0.108	0.838	0.505
(TR Quintiles 3 and 4)	(5.196)	(0.353)	(0.030)	(0.098)	(0.068)
more than 6 slaves	95.179	7.943	0.349	2.481	1.462
(TR Quintile 5)	(10.458)	(0.839)	(0.055)	(0.190)	(0.135)

NOTES: Own calculations from Inventory rolls. Means, with standard errors of means in parentheses. The slave categories were based on the average number of slaves for each of the quintiles in Table 2. Hence slave category 1 corresponds to quintiles 1 and 2, while category 2 corresponds to quintiles 3 and 4, and slave category 3 corresponds to quintile 5.

APPENDIX

Table 4 OLS Cobb-Douglas Regressions of Total-Value

		1700	1702	1705	1709	1712	1719	1723	1700	1702	1705	1709	1712	1719	1723
	log (Total Slaves)	0.149***	0.094*	0.151***	0.140***	0.195***	0.207***	-0.142**							
	log (Knechts)	0.004	0.077	0.059	0.067	0.003	-0.041	0.286***	0.017	0.053	0.064	0.111	0.079**	-0.013	0.231***
	log (Household Size)	-0.051	-0.099*	-0.136***	-0.146***	-0.058	-0.141*	-0.243***	-0.052	-0.074	-0.138***	-0.128***	-0.045	-0.177***	-0.168**
	log (Muids of Grain Sown)	0.621***	0.630***	0.525***	0.517***	0.529***	0.459***	0.531***	0.549***	0.481***	0.439***	0.424***	0.346***	0.251***	0.363***
	log (x1000 Vines Planted)	0.023**	0.02	0.006	-0.004	-0.004	-0.014	0.006	0.01	-0.004	-0.015	-0.021*	-0.015	-0.041***	-0.023**
	log (Horses)	0.148***	0.236***	0.191***	0.245***	0.095*	0.002	0.188***	0.107***	0.167***	0.174***	0.201***	0.043	-0.026	0.081**
log(Total Slaves) by Diversity Quintile	1								0.097	-0.135	0.036	0.011	-0.05	-0.115	-0.583***
	2								0.171*	-0.073	0.146**	0.174***	0.240***	0.138*	-0.001
	3								0.155***	0.245***	0.180***	0.193***	0.312***	0.217***	0.092
	4								0.215***	0.203***	0.179***	0.191***	0.228***	0.412***	0.192***
	5								0.200***	0.176***	0.242***	0.181***	0.241***	0.469***	0.214***
Diversity Quintile Dummies	1								-0.649***	-1.265***	-0.560***	-0.831***	-1.430***	-1.621***	-1.389***
	2								-0.06	-0.291**	-0.076	0.004	-0.199	0.072	0.470**
	3								-0.078	0.071	0.112	0.137	-0.258**	0.215	0.289*
	4								-0.074	0.027	0.028	-0.004	-0.024	0.104	0.085
	Constant	5.344***	5.572***	5.626***	6.075***	5.732***	5.702***	6.504***	5.651***	5.960***	5.830***	6.446***	6.399***	6.073***	6.380***
	N	231	254	219	280	295	327	365	231	254	219	280	295	327	365
	R-squared	0.887	0.761	0.814	0.8	0.756	0.485	0.509	0.901	0.811	0.837	0.832	0.841	0.689	0.726

NOTES: *Significant at 10% **Significant at 5% ***Significant at 1%. Own Calculations from *Opgaafrollen*. *Total Value* of marketable products is the number of leaguers of wine, muids of grain and number of sheep, cattle and pigs, each multiplied by their respective prices from the Master of the Orphan Chamber inventories, and deflated to 1700 prices by the overall price index of Du Plessis and Du Plessis (2009). Only 15% of total stocks are included in the quantity. Other quantities are measured in the units indicated, and are used to control for other production inputs. Coefficients on *log(Total Slaves)* are used to generate Values of the Marginal Product of Slaves for each individuals, as follows: $VMP_i^{slaves} = \beta^{\log(Total\ Salves)} * \frac{Total\ Value_i}{Total\ Slaves_i}$. The second half of the table estimates the coefficients separately for each quintile of product diversity and with fixed effects for these quintiles

Table 5 Quantile Regressions of log (Total Value) - 1700

	Quantile	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
	log(Total Slaves)	0.078	0.066	0.092*	0.074*	0.081**	0.110***	0.118***	0.119***	0.148***	0.170***	0.175***	0.183***	0.192***	0.182***	0.199***	0.199***	0.216***	0.229***	0.243***
	log(Knechts)	0.098	0.029	0.005	0.011	0.009	0.03	0.058	0.068	0.045	0.05	0.031	0.021	0.003	0.003	0.004	0.006	0.029	0.027	-0.009
	log(Household Size)	-0.112	-0.085	-0.095	-0.045	-0.037	-0.067	-0.066	-0.054	-0.048	-0.045	-0.032	-0.017	-0.029	-0.009	0.007	0.01	0.014	0.015	-0.006
	log(Muids of Grain Sown)	0.848***	0.819***	0.790***	0.725***	0.705***	0.689***	0.696***	0.653***	0.629***	0.633***	0.628***	0.608***	0.596***	0.610***	0.542***	0.525***	0.512***	0.473***	0.464***
	log(x1000 Vines Planted)	0.022	0.026**	0.024	0.034***	0.032***	0.034***	0.027***	0.028**	0.024*	0.021**	0.024***	0.024***	0.019**	0.015*	0.011	0.012*	0.011***	0.017**	0.013
	log(Horses)	0.042	0.107	0.129**	0.151***	0.148***	0.148***	0.138***	0.126***	0.129***	0.121***	0.111***	0.099***	0.100***	0.093***	0.100***	0.087***	0.070***	0.066*	0.073
	Constant	4.668***	4.655***	4.787***	4.870***	4.937***	5.078***	5.208***	5.301***	5.377***	5.473***	5.460***	5.490***	5.566***	5.607***	5.765***	5.822***	5.916***	5.963***	6.049***
	N	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231
	With Diversity Interactions																			
	log(Total Slaves)	0.038	0.04	0.047	-0.036	-0.048	-0.024	-0.015	-0.056	-0.013	0.047	0.096**	0.146***	0.146***	0.125***	0.117***	0.215***	0.280***	0.207***	0.297**
	log(Knechts)	0.049	0.091	0.051	-0.001	0.005	-0.018	0.032	0.05	0.038	0.033	0.019	0.012	0.015	0.019	0.034	0.034	-0.002	-0.004	-0.009
	log(Household Size)	0.025	-0.154	-0.139**	-0.044	-0.077	-0.079*	-0.079	-0.092*	-0.065	-0.032	0.005	0.018	0.014	0.009	0.004	0.001	-0.007	-0.02	-0.03
	log(Muids of Grain Sown)	0.675***	0.683***	0.658***	0.612***	0.625***	0.632***	0.628***	0.640***	0.652***	0.638***	0.606***	0.610***	0.590***	0.553***	0.528***	0.524***	0.521***	0.483***	0.492***
	log(x1000 Vines Planted)	0.015	0.01	0.01	0.005	0.005	-0.003	0.004	0.003	0.008	0.015	0.026***	0.019***	0.020**	0.018**	0.016**	0.016***	0.015**	-0.004	-0.003
	log(Horses)	0.095	0.051	0.08	0.103**	0.102***	0.108***	0.105**	0.113***	0.113**	0.089**	0.095***	0.093***	0.087***	0.082***	0.083***	0.087***	0.075***	0.075***	0.069
log(Total Slaves)	2	0.096	0.482	0.801***	0.785***	0.773***	0.831***	0.772***	0.812***	0.841***	0.666***	0.672***	0.521***	0.631***	0.577***	0.596***	0.381***	0.425***	0.309***	0.19
	3	0.682	0.844**	0.863***	0.817***	0.767***	0.831***	0.808***	0.655***	0.417*	0.273*	0.183	0.075	0.169	0.258*	0.374***	0.196	0.307**	0.365***	0.231
	4	0.486	0.59	0.700**	0.804***	0.712***	0.738***	0.701***	0.683***	0.463*	0.350*	0.244*	0.136	0.223	0.301*	0.463***	0.279**	0.245*	0.277*	0.2
	5	0.575	0.772*	0.845***	0.913***	0.811***	0.884***	0.911***	0.775***	0.570**	0.415**	0.287**	0.166**	0.264*	0.354**	0.472***	0.274**	0.251*	0.298**	0.135
Diversity Quintile	2	-0.097	0.076	0.188	0.156	0.193**	0.166**	0.108	0.241**	0.327**	0.226**	0.246***	0.167***	0.215***	0.166**	0.136**	0.027	0.039	0.01	-0.086
	3	0.052	0.109	0.089	0.144**	0.145*	0.140*	0.116	0.150*	0.106	0.06	0.01	-0.039	-0.035	-0.006	-0.005	-0.098*	-0.055	0.035	-0.027
	4	0.107	0.181	0.171**	0.265***	0.274***	0.255***	0.266***	0.228***	0.184*	0.141**	0.100*	0.054*	0.053	0.075	0.066	-0.027	-0.07	0.027	-0.056
	5	0.138	0.183	0.160**	0.225***	0.256***	0.272***	0.225**	0.249***	0.192*	0.141**	0.099*	0.057*	0.072	0.091*	0.095**	0	-0.045	0.052	-0.042
	Constant	4.252***	4.524***	4.475***	4.425***	4.553***	4.569***	4.662***	4.856***	5.014***	5.128***	5.162***	5.318***	5.283***	5.341***	5.337***	5.551***	5.582***	5.812***	5.974***
	N	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231

NOTES: *Significant at 10% **Significant at 5% ***Significant at 1%. Own Calculations from *Opgaafrollen*. Dependent Variable: log(*Total Value* of marketable products) is the number of leaguers of wine, muids of grain and number of sheep, cattle and pigs, each multiplied by their respective prices from the Master of the Orphan Chamber inventories, and deflated to 1700 prices by the overall price index of Du Plessis and Du Plessis (2009) and logged. Only 15% of total stocks are included in the quantity. Other quantities are measured in the units indicated, and are used to control for other production inputs. Coefficients on *log(Total Slaves)* are used to generate Values of the Marginal Product of Slaves for each individuals, as follows: $VMP_i^{slaves} = \beta^{\log(Total\ Salves)} * \frac{Total\ Value_i}{Total\ Slaves_i}$. The bottom half of the table estimates the coefficients separately for each quintile of product diversity and with fixed effects for these quintiles.

Table 6 Quantile Regressions of log(Total Value) - 1709

	Quantile	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
	log(Total Slaves)	0.223	0.182***	0.163***	0.163***	0.130***	0.152***	0.137***	0.137***	0.138***	0.140***	0.155***	0.167***	0.147***	0.150***	0.133***	0.145***	0.162***	0.092	0.101
	log(Knechts)	0.121	0.07	0.061	0.071	0.057	0.061	0.043	0.048	0.062	0.084*	0.061	0.02	0.023	0.011	0.055	0.02	0.016	0.07	0.265
	log(Household Size)	-0.166	-0.054	-0.021	-0.06	-0.064	-0.091	-0.079	-0.068*	-0.076*	-0.089**	-0.086	-0.101*	-0.122**	-0.134**	-0.219***	-0.224***	-0.248***	-0.269***	-0.263
	log(Muids of Grain Sown)	0.762***	0.680***	0.661***	0.619***	0.590***	0.583***	0.577***	0.570***	0.504***	0.488***	0.485***	0.467***	0.466***	0.437***	0.463***	0.462***	0.433***	0.411***	0.444***
	log(x1000 Vines Planted)	-0.034	-0.029	-0.017	-0.012	-0.009	-0.008	-0.005	-0.008	-0.009	-0.004	-0.001	0.002	0.005	0.01	0.011	0.006	0.012	0.032**	0.011
	log(Horses)	0.1	0.204***	0.224***	0.235***	0.276***	0.223***	0.221***	0.220***	0.275***	0.258***	0.251***	0.232***	0.227***	0.215***	0.196***	0.185***	0.162***	0.192**	0.104
	Constant	5.346***	5.304***	5.320***	5.476***	5.533***	5.721***	5.774***	5.818***	5.951***	6.055***	6.054***	6.138***	6.234***	6.316***	6.568***	6.645***	6.758***	6.941***	7.587***
	N	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280
	With Diversity Interactions																			
	log(Total Slaves)	0.259	0.134	0.069	0.154**	-0.009	-0.017	-0.028	-0.032	-0.039	-0.033	-0.095**	-0.088	-0.019	-0.037	-0.048	0.108	0.063	0.091	-0.118
	log(Knechts)	0.008	0.011	0.039	0.109	0.091	0.083	0.057	0.056	0.059	0.084	0.058	0.053	0.049	0.058	0.042	0.058	0.051	0.117	0.21
	log(Household Size)	-0.054	-0.109	-0.087	-0.07	-0.091	-0.087	-0.052	-0.045	-0.03	-0.053	-0.071*	-0.075*	-0.069	-0.098*	-0.121*	-0.170**	-0.241***	-0.247**	-0.297**
	log(Muids of Grain Sown)	0.364**	0.408***	0.430***	0.442***	0.451***	0.453***	0.462***	0.453***	0.457***	0.469***	0.415***	0.396***	0.366***	0.371***	0.383***	0.407***	0.378***	0.358***	0.368**
	log(x1000 Vines Planted)	-0.03	-0.028	-0.025	-0.028*	-0.019	-0.017	-0.020**	-0.016*	-0.018*	-0.015	-0.011	-0.01	-0.006	-0.01	-0.009	-0.001	0.003	0.023	0.031
	log(Horses)	0.288*	0.210***	0.187***	0.207***	0.215***	0.213***	0.217***	0.216***	0.223***	0.227***	0.226***	0.241***	0.220***	0.213***	0.206***	0.203***	0.189***	0.160*	0.082
log(Total Slaves) interacted with	2	1.38	1.243***	1.190***	0.981***	0.729***	0.723***	0.632***	0.796***	0.794***	0.693***	0.819***	0.843***	0.758***	0.769***	0.702***	0.411*	0.424**	0.391	0.907
	3	1.659	1.395***	1.200***	1.166***	0.811***	0.850***	0.871***	0.882***	0.888***	0.843***	0.953***	1.019***	0.871***	0.885***	0.802***	0.444*	0.466**	0.479	0.336
	4	1.361	1.272***	1.150***	0.933***	0.661***	0.616***	0.586***	0.647***	0.642***	0.586***	0.713***	0.757***	0.622***	0.837***	0.772***	0.506**	0.739***	0.59	0.509
	5	1.384	1.327***	1.189***	0.992***	0.573***	0.572***	0.515***	0.653***	0.677***	0.624***	0.643***	0.801***	0.756***	0.781***	0.771***	0.421	0.516**	0.586	0.39
Diversity Quintile Dummies	2	-0.044	0.103	0.117	-0.005	0.169*	0.167*	0.178**	0.265***	0.265***	0.244***	0.300***	0.288***	0.208***	0.218**	0.211*	0.018	0.081	0.064	0.073
	3	0.078	0.236**	0.281**	0.062	0.216**	0.211**	0.201***	0.217***	0.212***	0.192**	0.269***	0.246***	0.205***	0.214**	0.234**	0.066	0.128	0.081	0.32
	4	0.1	0.205*	0.202	0.101	0.260***	0.271***	0.267***	0.255***	0.260***	0.227***	0.301***	0.292***	0.251***	0.203**	0.256**	0.031	0.006	-0.022	0.237
	5	-0.01	0.031	0.129	0.052	0.223***	0.240**	0.264***	0.242***	0.227***	0.185**	0.295***	0.251***	0.170**	0.202**	0.194	0.062	0.125	0.041	0.389***
	Constant	3.992***	4.423***	4.656***	4.980***	5.294***	5.315***	5.342***	5.342***	5.354***	5.505***	5.505***	5.499***	5.678***	5.794***	5.891***	6.310***	6.452***	6.659***	7.070***
	N	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280	280

NOTES: *Significant at 10% **Significant at 5% ***Significant at 1%. Own Calculations from *Opgaafrollen*. Dependent Variable: log(*Total Value* of marketable products) is the number of leaguers of wine, muids of grain and number of sheep, cattle and pigs, each multiplied by their respective prices from the Master of the Orphan Chamber inventories, and deflated to 1700 prices by the overall price index of Du Plessis and Du Plessis (2009) and logged. Only 15% of total stocks are included in the quantity. Other quantities are measured in the units indicated, and are used to control for other production inputs. Coefficients on *log(Total Slaves)* are used to generate Values of the Marginal Product of Slaves for each individuals, as follows: $VMP_i^{slaves} = \beta^{\log(Total\ Salves)} * \frac{Total\ Value_i}{Total\ Slaves_i}$. The bottom half of the table estimates the coefficients separately for each quintile of product diversity and with fixed effects for these quintiles.

Table 7 Quantile Regressions of log (Total Value) - 1723

	Quantile	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
	log(Total Slaves)	-0.373	-0.291*	-0.192**	-0.072	-0.059	-0.008	-0.002	0.016	0.042	0.084***	0.088***	0.087***	0.058**	0.086***	0.140***	0.149***	0.167***	0.203***	0.177*
	log(Knechts)	0.494	0.284	0.330***	0.234**	0.216***	0.187**	0.214***	0.219***	0.199***	0.175***	0.215***	0.242***	0.250***	0.220***	0.203***	0.219***	0.213**	0.194**	0.232
	log(Household Size)	-0.095	-0.261	-0.209*	-0.138	-0.157**	-0.160*	-0.132***	-0.140**	-0.153***	-0.184***	-0.155***	-0.174***	-0.172***	-0.168***	-0.160***	-0.191***	-0.312***	-0.403***	-0.397
	log(Muids of Grain Sown)	1.056***	0.785***	0.702***	0.570***	0.507***	0.496***	0.497***	0.476***	0.448***	0.422***	0.401***	0.389***	0.378***	0.364***	0.317***	0.294***	0.303***	0.295***	0.286*
	log(x1000 Vines Planted)	-0.002	0.007	0.001	-0.008	-0.001	-0.007	-0.012	-0.013	-0.014	-0.007	-0.013	-0.019**	-0.021***	-0.014**	-0.017***	-0.014	-0.008	0.003	0.008
	log(Horses)	0.233	0.365***	0.277***	0.270***	0.274***	0.211***	0.178***	0.168***	0.154***	0.116***	0.107***	0.114***	0.130***	0.103***	0.088***	0.075*	0.022	-0.044	-0.086
	Constant	4.626***	5.254***	5.601***	5.703***	5.864***	6.004***	6.142***	6.231***	6.322***	6.398***	6.525***	6.689***	6.797***	6.791***	6.841***	6.983***	7.258***	7.508***	7.803***
	N	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365
	With Diversity Interactions																			
	log(Total Slaves)	-0.998***	-0.897***	-0.849***	-0.856***	-0.807***	-0.852***	-0.867***	-0.848***	-0.857***	-0.646***	-0.614***	-0.586***	-0.408***	-0.338***	-0.320***	-0.250***	-0.251***	-0.169***	0.073
	log(Knechts)	0.104	0.088	0.056	0.105	0.11	0.138**	0.123*	0.187**	0.168**	0.187***	0.195***	0.213***	0.185***	0.183***	0.172***	0.173***	0.184***	0.160**	0.302
	log(Household Size)	-0.121	-0.113	-0.077	-0.113	-0.130*	-0.123*	-0.125*	-0.105	-0.088	-0.083**	-0.078**	-0.099**	-0.144***	-0.123***	-0.120**	-0.172***	-0.151**	-0.148***	-0.15
	log(Muids of Grain Sown)	0.331	0.377***	0.417***	0.438***	0.470***	0.451***	0.390***	0.384***	0.384***	0.379***	0.379***	0.393***	0.377***	0.377***	0.375***	0.370***	0.368***	0.398***	0.399**
	log(x1000 Vines Planted)	-0.018	-0.012	-0.011	-0.017	-0.021	-0.025**	-0.021*	-0.02	-0.017	-0.015**	-0.014**	-0.013*	-0.014**	-0.016**	-0.01	-0.006	-0.002	0.005	0.015
	log(Horses)	0.265	0.230***	0.181***	0.172***	0.139***	0.139***	0.127***	0.108**	0.113***	0.096***	0.081***	0.084***	0.086***	0.041*	0.028	0.016	0.012	0	-0.067
log(Total Slaves) interacted with	2	2.053***	2.039***	2.207***	2.219***	2.317***	2.394***	2.198***	2.188***	2.066***	1.813***	1.806***	1.695***	1.378***	1.417***	1.318***	1.274***	1.401***	1.579***	1.497**
	3	2.186**	2.038***	2.142***	2.104***	2.056***	2.091***	2.115***	2.052***	1.910***	1.598***	1.598***	1.448***	1.076***	0.916***	0.735***	0.743***	0.833***	0.948***	0.606
	4	2.275*	2.071***	1.871***	1.921***	1.869***	1.931***	1.927***	1.857***	1.753***	1.443***	1.412***	1.239***	0.856***	0.711***	0.532***	0.435***	0.386**	0.19	-0.148
	5	2.370*	2.056***	1.743***	1.626***	1.566***	1.577***	1.553***	1.679***	1.471***	1.298***	1.253***	1.167***	0.727***	0.629***	0.421*	0.281	0.194	-0.04	-0.216
Diversity Quintile Dummies	2	0.832***	0.823***	0.819***	0.804***	0.805***	0.841***	0.848***	0.834***	0.828***	0.637***	0.622***	0.605***	0.427***	0.434***	0.415***	0.358***	0.312***	0.196***	-0.213
	3	1.131***	0.999***	0.937***	0.919***	0.863***	0.904***	0.953***	0.931***	0.930***	0.741***	0.706***	0.676***	0.516***	0.487***	0.469***	0.369***	0.300***	0.123	-0.177
	4	1.062***	1.030***	1.042***	1.035***	1.020***	1.007***	1.019***	1.004***	1.006***	0.792***	0.762***	0.733***	0.575***	0.544***	0.533***	0.475***	0.511***	0.438***	0.229
	5	1.033***	1.057***	1.089***	1.114***	1.086***	1.132***	1.192***	1.083***	1.145***	0.890***	0.862***	0.788***	0.636***	0.596***	0.589***	0.521***	0.507***	0.430***	0.152
	Constant	3.169***	3.468***	3.534***	3.796***	3.927***	4.061***	4.188***	4.379***	4.500***	4.868***	4.932***	5.166***	5.641***	5.796***	5.972***	6.200***	6.292***	6.446***	7.086***
	N	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365	365

NOTES: *Significant at 10% **Significant at 5% ***Significant at 1%. Own Calculations from *Opgaafrollen*. Dependent Variable: log(*Total Value* of marketable products) is the number of leaguers of wine, muids of grain and number of sheep, cattle and pigs, each multiplied by their respective prices from the Master of the Orphan Chamber inventories, and deflated to 1700 prices by the overall price index of Du Plessis and Du Plessis (2009) and logged. Only 15% of total stocks are included in the quantity. Other quantities are measured in the units indicated, and are used to control for other production inputs. Coefficients on *log(Total Slaves)* are used to generate Values of the Marginal Product of Slaves for each individuals, as follows: $VMP_i^{slaves} = \beta^{\log(Total\ Salves)} * \frac{Total\ Value_i}{Total\ Slaves_i}$. The bottom half of the table estimates the coefficients separately for each quintile of product diversity and with fixed effects for these quintiles.