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Modelling Long-term Commodities: the development of a Simulation Model for the South African Wine Industry within a Partial Equilibrium Framework

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Abstract

Econometric demand and supply models of agricultural commodities and crops have been around for a long time with extensive research and adaptations being made in the grain and livestock sectors. This much attention has, however, not been afforded to long term commodities. This paper presents a partial equilibrium framework for modelling long term commodities using the South African wine industry as an example. The model structure and important assumptions are presented, after which the usefulness of the model is tested in the form of baseline projections and the analysis of a typical "what if" question. The wine model presented in this paper is housed and maintained in the Bureau for Food and Agricultural Policy (BFAP) at the Department of Agriculture, Western Cape and the Universities of Pretoria and Stellenbosch.

Keywords: partial equilibrium, wine industry, baseline projections.

I. Introduction

The South African wine industry dates back to 1655, became economically significant during and after the Napoleonic wars, and has its roots as a modern industry in the beginning of the 20th century. The first vines were planted shortly after the Dutch settlement in Cape Town; in the early 19th century, vines planted increased from 15 million in 1808-1810 to 32 million in 1823-25 (compared to more than 300 million today), and wine made up more than 90 percent of exports from the Cape Colony (Keegan, 1996). By the beginning of the 20th century wine farmers had faced decades of disruptions, principally caused by the surplus production of low quality wine (Vink *et al.*,

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2004). This resulted in the establishment of the KWV in 1918, its registration as a company in 1923, and the promulgation of the Wine and Spirits Control Act, No 5 of 1924, which conferred statutory powers on the KWV. These powers lasted until 1997, when the industry was deregulated along with the rest of South African agriculture (Kassier, 1997).

With deregulation came increasing levels of uncertainty as the industry now had to compete in the international arena with a legacy of producing large quantities of cheap wine for the domestic market. Thus, if the industry is to remain viable in the face of global market forces it needs to be more forward thinking and produce more premium cultivars targeted at producing higher quality wine (Vink *et al.*, 2004).

Several models have been built to test the effect of macroeconomic variables on long term commodities (e.g. Wickens and Greenfield, 1973, Askari and Cummings, 1976, 1977, Bond, 1983, Remali and Zulkifli, 1998, and Alias and Cheong Tang, 2005). The purpose of this article is to describe the structure of a dynamic, recursive partial equilibrium model of the South African wine industry targeted at assisting the industry with scenario analysis by answering "what if" type questions.

II. Data

All domestic vine, production, consumption, and export data were obtained from the South African Wine Industry Council's information unit, South African Wine Information and Systems (SAWIS), with most data available from 1985. International wine prices and export volumes were obtained from the Compendium of Wine Statistics (Wittwer and Rothfield, 2006), while prices for competing crops and fruit types were obtained from the Abstract of Agricultural Statistics (Abstract, 2006). South African macroeconomic variables as well as exchange rates were obtained from the South African Reserve Bank and Statistics South Africa websites.

III. The basic model

The methodology developed by the Food and Agricultural Policy Research Institute

(FAPRI) at the University of Missouri has proven convenient for conducting scenario planning and policy analysis (Meyer and Kirsten, 2005) and underpins the approach used for modelling the South African wine sector. In this article, the FAPRI methodology is adapted to suit the nature of a long-term commodity such as wine. Since the principle objective of this research is to develop a well-behaved econometric model that is able to capture the salient features of the wine industry, alternative estimation and validation procedures are followed in some cases to find estimates that provide an accurate prediction of reality. Where necessary, synthetic parameters are imposed to ensure reasonable model behaviour.

A. *The wine grape supply block*

The South African wine industry can be divided into eight main producing regions, each better suited to certain varietals. Vine bearing numbers change over time due to new plantings and the removal of older less productive vines. The number of vines per hectare can also vary for a number of different reasons such as location, slope, varietals, and trellising practice. It is for this reason that the total number of vines rather than hectares planted to vines is modelled. The model makes provision for the ten main varietals produced in South Africa as well as for the eight producing regions. The number of varieties modelled individually is based on their percentage contribution to the total number of vines within the region, with a minimum contribution of 1%. Varietals not modelled individually are included in “other white” and “other red”. Table 1 reports the varietals modelled individually per region.

When modelling the supply of perennial crops, there are a number of options available to the researcher: the first is to model “new plantings” which after four years are added to total number of bearing vines, while uprooted vines are simply subtracted. The second option is to model “change in vine numbers” per year and then adding this, with the four year lag if positive, to the total number of bearing vines. This option would eliminate the inclusion of replacement vines. The third and possibly simpler option is to model “vine bearing numbers” directly. This option would reduce the number of equations required and by lagging the grape price term by four years, eliminate the need to adjust between vine numbers and bearing vines. Given the number of regions and varietals included in the model, the third option was preferred. The usefulness of following this approach will be illustrated in section IV of this paper, where the model is used to simulate the impact of a shock in the exchange rate.

Table 1: Varietals modelled individually per region

Varietals	Region In Which Individually Modelled
Cabernet Sauvignon	Malmesbury, Paarl, Robertson, Stellenbosch
Chardonnay	Little Karoo, Malmesbury, Olifants River, Paarl, Robertson, Stellenbosch, Worcester
Chenin Blanc	Little Karoo, Malmesbury, Olifants River, Orange River, Paarl, Robertson, Stellenbosch, Worcester
Cinsaut Noir	Malmesbury, Paarl, Stellenbosch, Worcester
Colombar	Little Karoo, Malmesbury, Olifants River, Orange River, Paarl, Robertson, Worcester
Merlot	Malmesbury, Olifants River, Paarl, Stellenbosch, Worcester
Pinotage	Malmesbury, Olifants River, Paarl, Stellenbosch, Worcester
Sauvignon Blanc	Malmesbury, Olifants River, Paarl, Robertson, Stellenbosch
Shiraz	Malmesbury, Olifants River, Paarl, Robertson, Stellenbosch, Worcester
Sultana	Orange River
Other Red	Little Karoo, Malmesbury, Olifants River, Orange River, Paarl, Robertson, Stellenbosch, Worcester
Other White	Little Karoo, Malmesbury, Olifants River, Orange River, Paarl, Robertson, Stellenbosch, Worcester

To allow for cross price elasticities as well as inter-varietal elasticities, supply was modelled in two steps, in order to conserve degrees of freedom given the large number of varietals. The two steps were based on the assumption that the farmer has to make two main decisions that impact on wine grape supply. The first decision is whether to plant vines, orchards, or other alternative crops suitable to the particular region. Following this, the farmer still needs to decide which varietals to plant.

All supply equations are driven by a type of real expected gross return variable. Real expected gross return (*EGRT*) is calculated as the average yield per variety multiplied by the expected price per variety, deflated by the Gross Domestic Product (GDP) deflator. Within each region, total vine numbers (*TVP*) are estimated as a function of the previous year’s total vine numbers, the weighted sum of all the varietals’ expected real gross return (*WEGRT*) lagged four years, and the real price of competing fruit trees or crops (*ALTC*), also lagged four years.

$$TVP_t = f(TVP_{t-1}; WEGRT_{t-4}; ALTC_{t-4}) \qquad (1)$$

Vine numbers for the individual varietals are expressed as the share of the total vines in the region (*VPSH*), and are estimated as a function of the real gross expected return to the particular variety ($EGRT_{it-4}$) divided by the weighted sum of the expected real gross returns ($WEGRT_{it-4}$) to all the other varietals. This is applied to the varietals specified in each region. The advantage is that it allows for the determination of cross price elasticities with competing crops as well as cross price elasticities among the different varietals. This technique also allows the modeller to construct a cross price elasticity matrix for the various varietals in each of the production regions.

$$VPSH_{it} = f\left(\frac{EGRT_{it-4}}{sum(WEGRT_{it-4})}\right) \qquad (2)$$

Vine numbers per variety (TVP_i) can now be calculated by multiplying the total vine numbers (*TVP*) by the share for the particular variety ($VPSH_i$)

$$TVP_i = TVP \times VPSH_i \qquad (3)$$

Trellising practices, slope, wind and rain, and cultivar all affect yield ($YIELD_i$). Because the specific micro climate on each farm significantly affects yields, a five year moving average yield was used to determine total grape production per variety ($PRODGR_i$).

$$PRODGR_i = TVP_i \times YIELD_i \qquad (4)$$

Specification of the transition from wine grapes to wine is not simple, as there is no average extraction rate or conversion rate from grapes to wine per variety. This, combined with the fact that there are no data that specify which grapes or variety of grapes was used in the production of wine as opposed to other products such as rebate wine[4], distillates, or grape juice concentrate, required a drastic simplification in the estimation of wine production. The production of wine (*PRODW*) is therefore estimated as a function of total red wine grapes produced (*PRODGRR*), total white wine grapes produced (*PRODGRW*) and the average real wine price (*RWINEPR*). Similarly, the production of rebate wine (*PRODR*) and distillates (*PRODD*) is estimated as a function of total white wine grapes produced and the real price of rebate wine (*RRBPR*) and distillates (*RDIPR*) respectively. On average, the total litres of fluid (wine, distillates, rebate wine, or grape juice concentrate) produced from one ton of wine grapes is 850 litres. Thus grape juice concentrate production is calculated by multiplying the total wine grape crop by 0.85 and subtracting the estimated wine, rebate wine and distillates production.

$$PRODW_t = f(PRODGRR_t; PRODGRW_t; RWINEPR_t) \qquad (5)$$

B. *The wine demand block*

The demand for wine is broken down into two main segments, namely domestic demand and export demand. While the demand curve of a product relative to its own price is conventionally downward sloping, wine economists might argue that higher prices can actually increase demand as a consumer's perception of wine quality is positively related to its price. Larivière *et al.*, (2000) compiled a table of own price elasticities for wine indicating that the own price elasticity varies from -1.35 to 0.16. For the purpose of this model however, no quality distinction was made between different wines due to a lack of relevant data. For this reason, wine is considered a commodity having specific consistent quality attributes.

As stated previously, the demand for South African wine can be divided into domestic (*DOMCON*) and export (*EXP*) demand. Domestic demand was estimated, in terms of per capita consumption (*PCCON*), as a function of the real wine price (*RWINEPR*) and per capita GDP (*PCGDP*).

[4] In the South African industry, wine that is destined for the production of brandy is exempt from excise duties, hence rebate wine.

$$PCCON_t = f(RWINEPR_t; RRBPR_t; PCGDP_t) \quad (6)$$

Interestingly, the real rebate wine price proved to be the only price that was statistically significant compared to the other alcoholic beverages tested. Per capita GDP represents the income level of the population; this coefficient is expected to have a positive sign.

Export demand was disaggregated into red and white wine exports per country for the United Kingdom, the Netherlands, Germany, Scandinavia, Australasia, Canada, Belgium, France, the USA, and other countries. Exports were disaggregated into white and red wine exports because the elasticities proved to be statistically different. Export demand per country was estimated as a function of lagged exports as consumers acquire a taste for South African wines, the Rand/US Dollar (*EXCH*) or Rand/Euro (*REUR*) exchange rate depending on the importing country, the real 'good wine' price[5], and a weighted average "new world" wine price. The weighted average "new world" wine price (*NEWW*) was calculated using the wine export prices of Spain, Australia, New Zealand, USA, Chile, and Argentina together with their export volumes as weights.

$$EXP_t = f(EXP_{t-1}; EXCH_t; REUR_t; RWINEPR_t; NEWW_t) \quad (7)$$

C. *The closing block*

Reaching equilibrium in a partial equilibrium framework requires that total demand needs to equal total supply. Demand and supply components within a model cannot reach equilibrium without price and stock components. This section will discuss the price equations in the framework that allow the supply and demand blocks to interact, as well as the closing equation that allows equilibrium to be reached.

The wine varietals included individually in this framework can be divided into two broad categories: noble and non-noble varietals. The distinction is made because noble varietals are more likely to be made into wine as opposed to rebate wine, distillates or grape juice

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[5] 'Good wine' is a broad term used in the South African industry to describe wine intended for drinking purposes, i.e. natural, fortified and sparkling wine (Kassier, 1997).

concentrate. For this reason, noble varietals' real grape price (*RNGPR*) is estimated as a function of the lagged price of the said variety, the real wine price, and total production of the variety in question. Non-noble varietals' real grape price (*RNNGPR*) is estimated as a function of the lagged varietals' grape price, total production of the particular variety and the price of rebate wine and distillates. The above price equations thus create the link between the primary commodity "grapes" and the secondary commodity "wine".

$$RNGPR_{it} = f(RNGPR_{it-1}; RWINEPR_t; PRODGR_{it}) \tag{8}$$

$$RNNGRP_{it} = f(RNNGPR_{it-1}; PRODGR_{it}; RRBP_t; RDIPR_t) \tag{9}$$

The real average wine price is estimated as a function of producer sales of wine, wine production and the Rand/US Dollar exchange rate. The real rebate wine price is estimated as a function of the real wine price and rebate wine production. Distillates' real price is estimated as a function of the rebate wine price and distillates production.

$$RWINEP_t = f(DOMCON_t + EXP_t; PRODW_t; EXCH_t) \tag{10}$$

$$RRBP_t = f(RWINEP_t; PRODR_t) \tag{11}$$

$$RDIPR_t = f(RRBP_t; PRODD_t) \tag{12}$$

Having created links between supply and demand using price equations, the final step is an equilibrating identity which is derived from basic economic theory, namely that supply should equal demand. The equilibrating equation can take many forms depending on how one chooses to close the system. This system was closed using "change in stock". The change in stock levels is equal to wine production plus wine imports, less exports and domestic consumption. Figure 1 shows a general outline of the partial equilibrium model.

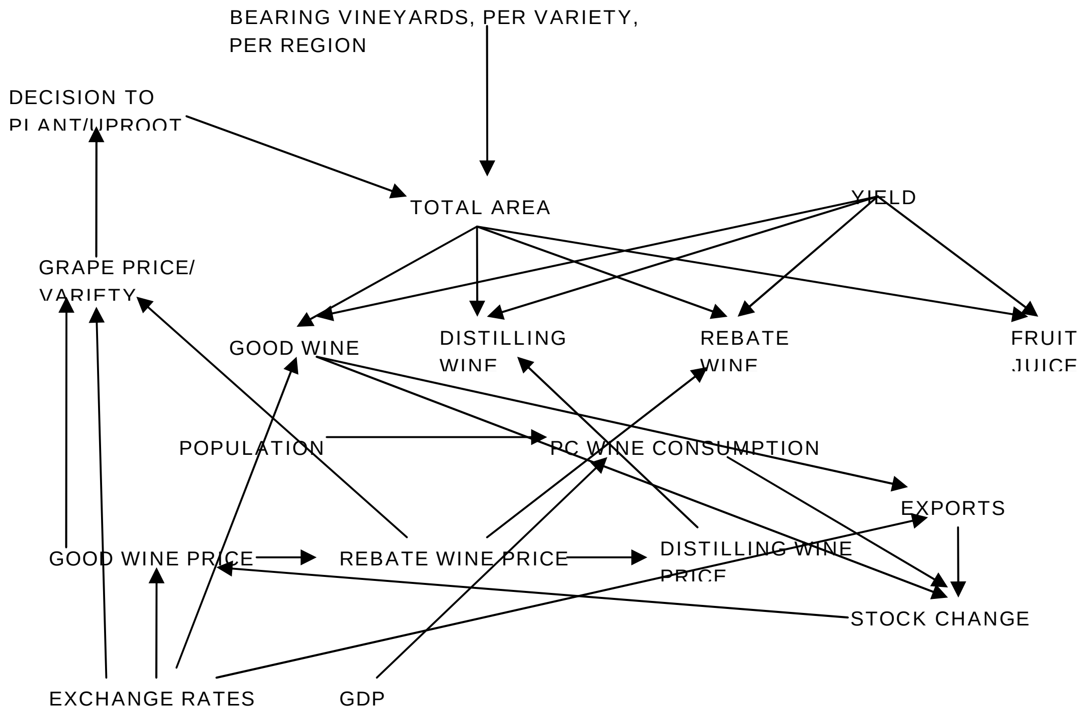

Figure 1: Broad representation of the South African wine industry partial equilibrium model

IV. South African wine industry outlook

The partial equilibrium framework allows for the development of representative outlooks, based on assumptions about exogenous variables. To enable the analysis of various external shocks on an industry, one needs a benchmark or starting point from where the deviations can be measured. This benchmark is referred to as a “Baseline”. The baseline simulations illustrate the possible outcomes given a certain set of assumptions. In the case of the wine model, these include the prices of alternative products, e.g. apricots. It is assumed, for the purpose of this outlook, that these prices remain constant at their average 2004 to 2006 prices. Macroeconomic assumptions are treated in a different manner. The outlook for all the macroeconomic variables was obtained from Global Insight (2007). Global Insight provides economical, political and financial coverage and forecasts for over 200 countries. Table 2 reports the assumptions made about various macroeconomic variables included in the framework.

Table 2: Macroeconomic assumptions

Macro Variables	2007	2008	2009	2010	2011	2012	2013	2014
Real GDP/ Capita R1000	17.3	18.2	19.1	20.2	21.3	22.5	23.8	25.3
GDP deflator (2000 = constant)	156	162	168	175	183	191	199	207
SA cents / €	855	867	899	989	1071	1146	1205	1249
SA cents / US $	747	793	846	895	939	984	1033	1083
Total population of SA in millions	47.4	47.6	47.8	48.0	48.1	48.3	48.5	48.7

Source: Global Insight, 2007.

Based on the above assumptions and actual data to 2006, the simulation model generates the baseline for the wine industry over the period 2007 to 2014. The baseline for selected production and consumption variables is presented in Figures 2, 3 and 4.

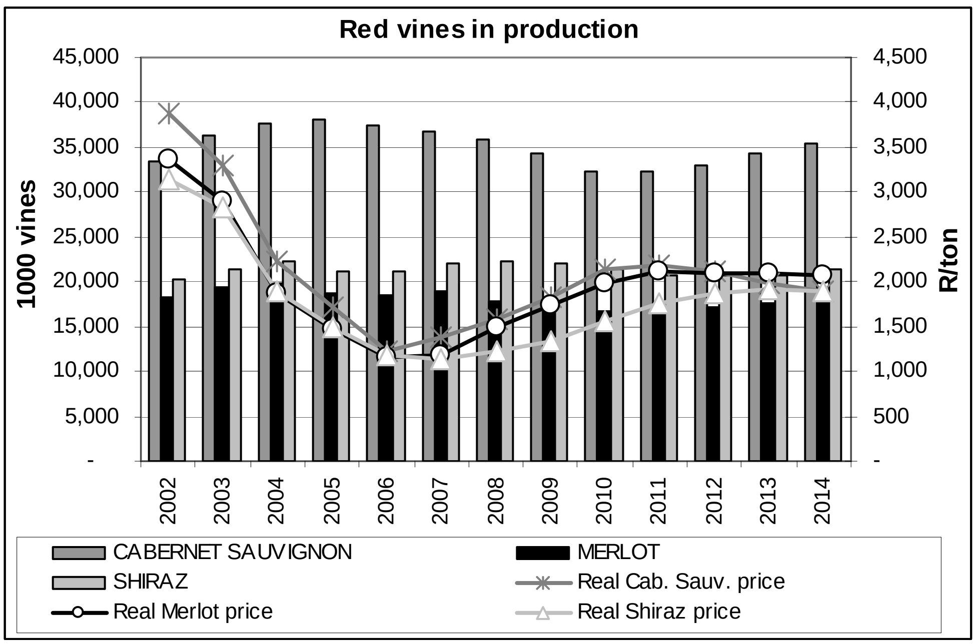

Figure 2: Outlook of selected red vines in production and red wine grape prices

During the nineties there has been a strong tendency to replace old vineyards with red varieties, a phenomenon that was not unique to South Africa. The increased plantings, and thus increased production, of red wine grapes has resulted in a relative surplus not only domestically but also internationally, which has resulted in a decrease in real red grape prices (see Figure 2). Producers responded to the falling prices by shifting new plantings to white varieties, resulting in a declined area under red wine grapes in early 2000-2001. Figure 2 shows the corresponding decline in vines in production of Cabernet Sauvignon grapes from 2006. This declining trend is expected to continue until 2010. Merlot and Shiraz grape vines in production declined in 2005, remained stable in 2006 and are projected to increase slightly in 2007, where after it is projected to decline up to 2011. The constant vines in production in 2006 and the projected increase in 2007 are due to higher yields in 2002 and 2003 increasing returns per vines, despite declining grape prices. Real prices of Cabernet Sauvignon and Merlot grapes are projected to turn upwards in 2007 due to the projected increase in producer sales, the projected depreciation in the Rand and, in the case of Cabernet Sauvignon, lower supply. The real Shiraz price is expected to decrease in 2007 due to a projected increase in supply, where after the price of Shiraz grapes is also expected to increase. In response to increasing prices, plantings are projected to increase leading to vines in production to enter an upward trend from 2011 onwards. The increase in supply of Cabernet Sauvignon grapes from 2011 to 2014 puts downward pressure on the price, and it is expected that prices will enter a declining phase from 2012 to 2014. A similar trend is projected for Merlot and Shiraz grapes.

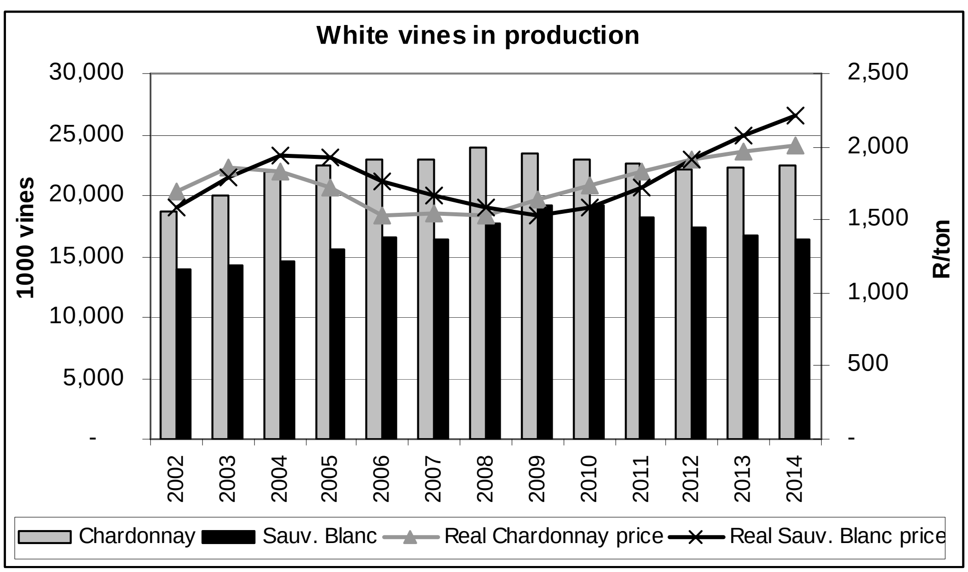

Figure 3: Outlook of selected white vines in production and white wine grape prices

The replacement of old vineyards with red varieties during the 1990s and the resulting oversupply of red wine was accompanied by a relative shortage in the production of white wine, increasing prices of white grape varieties. Increasing prices of white grape varieties and declining prices of red grape varieties during the early 2000s led to new plantings shifting to white varieties. Supply of white grapes increased as vines came into full production approximately 4 years later. The increase in supply, lower export growth (the volume of exports actually declined in 2006) and the stagnant domestic market, resulted in the prices of white grape varieties coming under pressure in 2004. Since then the prices of white grapes followed a downward trend. Sauvignon Blanc is the only white variety that experienced positive growth in 2004, but also entered a downward trend from 2005. Figure 3 shows that the vines in production of Sauvignon Blanc grapes are projected to increase up to 2009 as new plantings come into full production. This increase in supply puts downward pressure on prices and prices are projected to continue the downward trend up to 2009, before they start increasing again. The price of Chardonnay is first projected to stabilise in 2007 as supply (vines in production) remains stable, and then decline slightly in 2008 as supply increases, but thereafter projected to increase over the remainder of the baseline period.

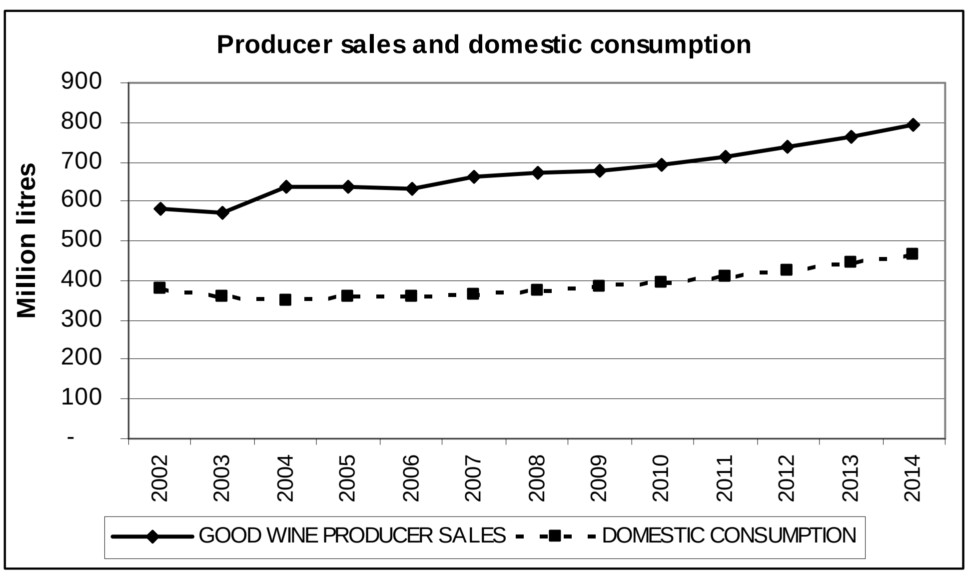

Figure 4: Outlook of good wine producer sales and domestic consumption

Figure 4 illustrates that producer sales increased steadily between 2002 and 2005. This increase was largely due to increases in exports, as domestic consumption remained relatively stable at between 300 and 400 million litres per annum. Producer sales decreased slightly in 2006 due to lower exports and stagnant domestic demand, but the projected increases in exports and domestic demand result in increased producer sales over the baseline period. Domestic consumption is projected to increase as total population and per capita income increases.

V. Application of the model to real-world issues

As stated previously, the baseline can be used as a benchmark to understand the impact of external shocks on the industry. These shocks can be calculated as absolute and percentage deviations from the baseline. The wine industry is to a large extent export driven; hence the exchange rate is one of the critical external drivers in the model. The industry is aware of the risks embedded in a highly volatile exchange rate and is constantly raising questions regarding its impact. In this section, therefore, the possible impact of an appreciation in the exchange rate (relative to the baseline) over time is investigated. For illustrative purposes, it is assumed that the exchange rate stays fixed against the US dollar at the baseline projection level of 2007 instead of depreciating over time. In other words, the exchange rate trades at 747 SA c/ US $ over the baseline period. The baseline assumption on the US $ / € rate remains unchanged and consequently the South African currency fluctuates between 794 SA c / € and 872 SA c / € over the baseline period (as opposed to depreciating gradually to 1249 SA c / € by 2014). Figures 5 to 8 present the deviations from the baseline as percentage changes.

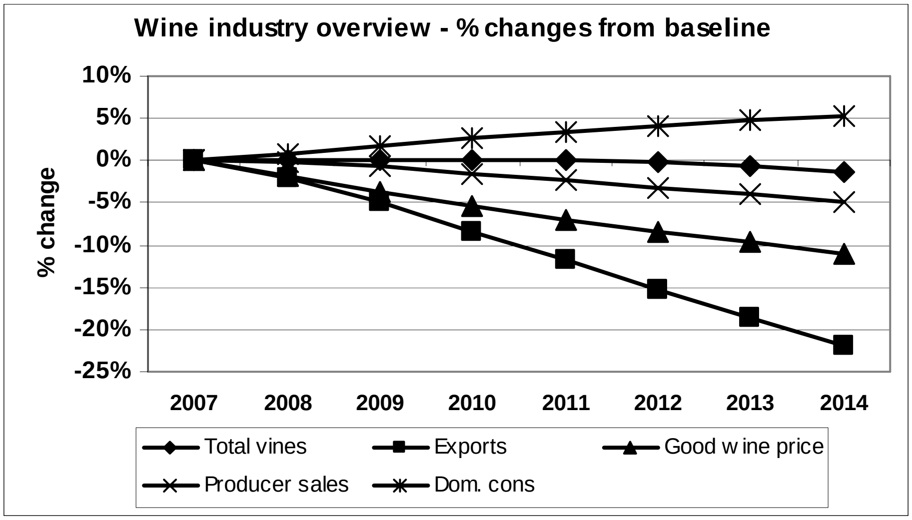

Figure 5: Wine industry overview – percentage change from baseline

Figure 5 presents a summary of the supply, demand, exports and price components in the model. The simulation results indicate that a strengthening in the exchange rate drives down prices because earnings in export markets decrease. Exports are projected to decrease by 20% below baseline levels in 2014. Domestic consumption is expected to increase, due to lower wine prices, but the decline in exports exceeds the increase in domestic consumption.

The impact of lower prices on vines in production is illustrated in Figures 6 and 7. Figure 6 shows that Shiraz vines in production are projected to decrease by 5.1% below the baseline by 2014, while the impact on Pinotage and Merlot is 4% and 2.5% respectively. Interestingly enough, the Colombar vines in production increase. This can be explained by the fact that Colombar not only has relatively high yields, but also the fact that the grapes are mostly used for distilled or rebate wine, which is mainly for the South African market. Important to note is that the exchange rate shock that was introduced in 2008 basically only takes affect on the vines in production in 2012.

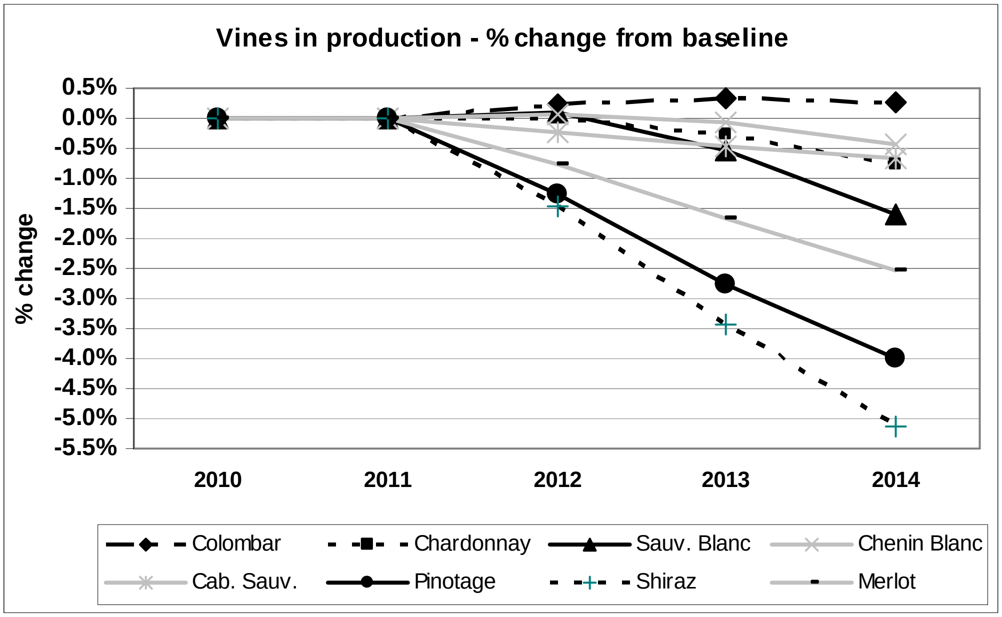

Figure 6: Total vines in production – percentage change from baseline

Figure 7 presents an interesting summary of the impact on prices and as a consequence the impact on vines in production 4 years later. This presentation clearly shows the relative sensitivity of each variety with respect to an exchange rate shock. Red wines are generally more affected by the exchange rate than white wines because of the greater dependence of red wines on the export market.

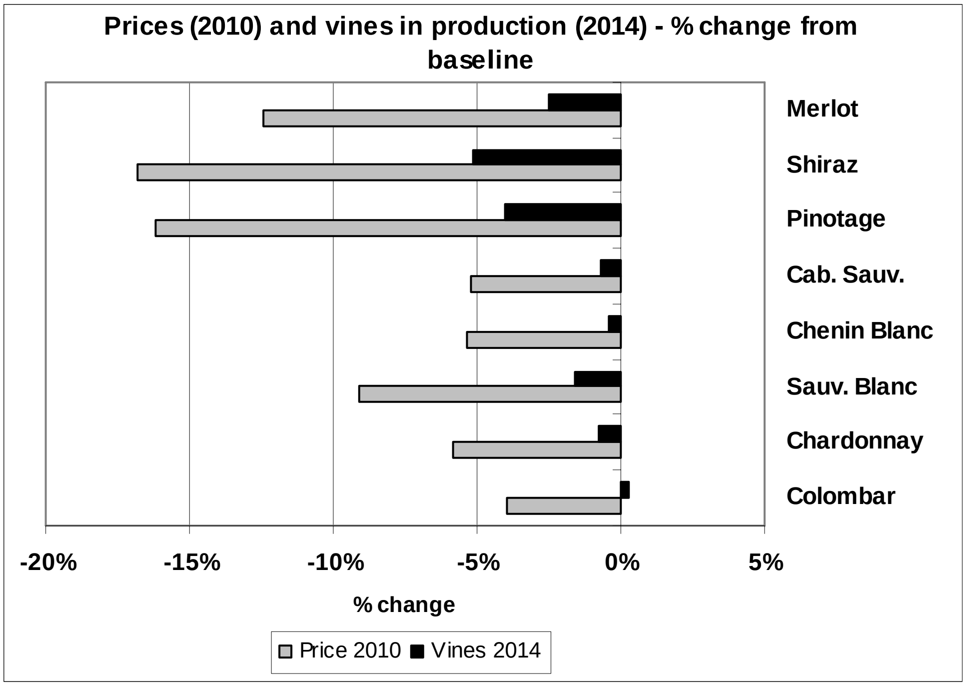

Figure 7: Prices (2010) and vines in production (2014) – percentage change from baseline

Figures 8 and 9 present the impact on vines in production for the different wine producing regions. These clearly illustrate the benefit of the model structure (discussed in section III) in the sense that a distinction can be made between the impact of the exchange rate shock at a national and regional level. Figure 8 shows that the impact on the different varieties in the Malmesbury region is similar to that of the entire industry (see Figure 6), where Shiraz is also the variety most affected by the appreciation in the exchange rate. However, the extent of the impact differs. For the industry as a whole, the impact on vines in production ranges between -5.1% and 0.3% and for the Malmesbury area, the impact ranges between -4.7% and 1.2% (compare Figures 6 and 8). This suggests that the impact of an exchange rate shock in the Malmesbury area is small relative to some other wine producing regions in South Africa. The results presented in Figure 9 confirm this reasoning.

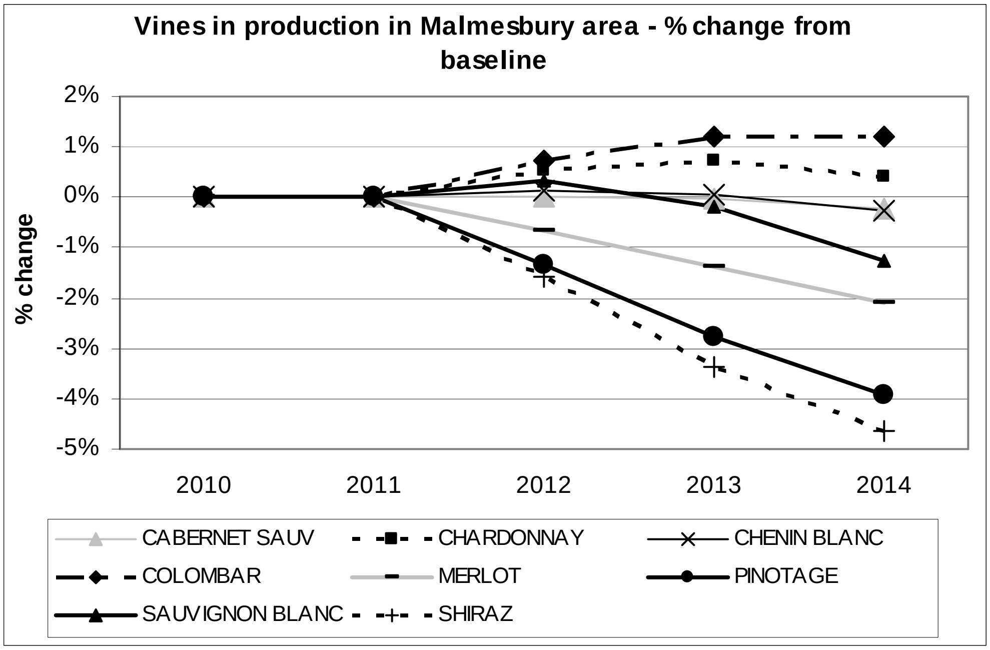

Figure 8: Vines in production, Malmesbury – percentage change from baseline

Figure 9 illustrates that the Paarl region is projected to experience the biggest contraction in the wine industry, resulting from an appreciation in the exchange rate. This can be explained by the fact that Paarl is predominantly a red wine producing region and also the area under wine grapes (modelled as vines in production) in the Paarl region is relative sensitive to price changes. The impact on Stellenbosch, which is also predominantly a red wine producing area, is smaller than in Paarl, as area under wine grapes around Stellenbosch is relative insensitive to price changes. The Little Karoo is predominantly a white wine producing region and the price elasticity of area under wine grapes is very low; therefore the impact on this region is very small. The price elasticity or price sensitivity of area under wine grapes in the various regions depends on a number of possible factors, including profit margins, availability of alternative crops, availability of land and the history or culture of wine production in that particular region.

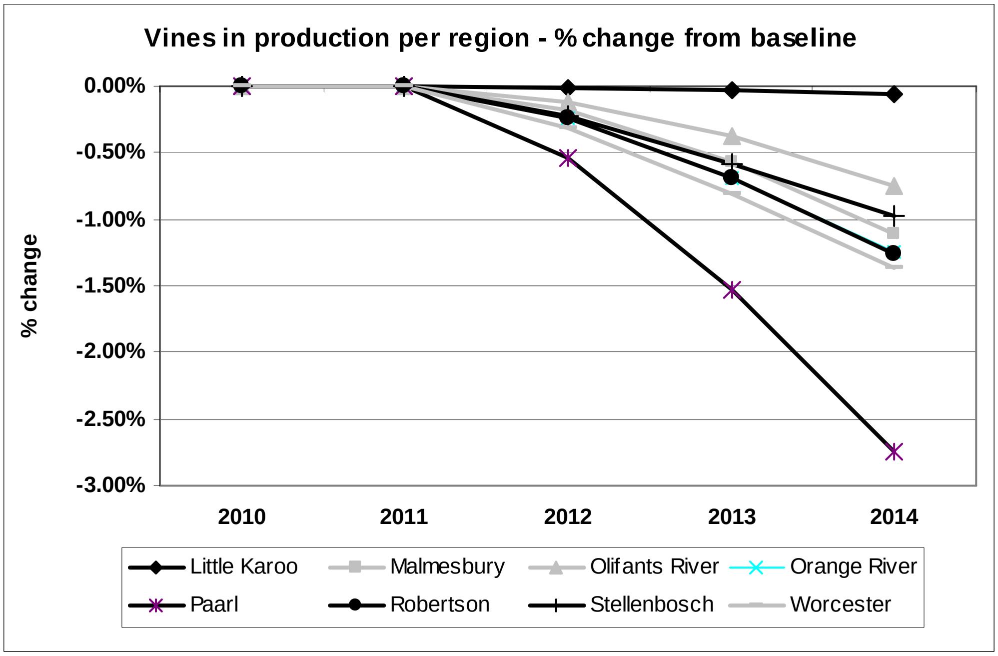

Figure 9: Vines in production per region – percentage change from baseline

VI. Conclusion

This paper has presented a partial equilibrium framework for modelling long term commodities as well as the usefulness of a simulation model for decision-makers in the South African wine industry. Baseline projections provide the industry with a benchmark of possible prices, production, consumption and trade under a certain set of assumptions. This benchmark can be used to better understand the impact of external shocks on the industry by means of calculating the absolute and percentage deviations from the baseline once a shock has been introduced in the model. However, the true usefulness of simulation models of this nature lies in the analysis of multiple shocks: in other words, the impact of a combination of shocks on the industry. These shocks include shifts in weather patterns, policy and tax structures, world prices, income, population and many more. Scenario planning can be useful to design a sequence of possible events/shocks that can be introduced in the model. Scenarios represent a sequence of events that take place in a logical way in order to present the possible outcome of reality (Meyer, 2006). Industry role players now have a tool that provides them the opportunity to better understand the possible impact of external shocks on the industry and how these shocks could influence their business. These models can, therefore, serve as an educational tool by teaching the modeller and the decision makers more about the dynamics of the industry.

The introduction of risk and the quantification thereof will further assist the decision maker in understanding the dynamics of the industry and making sound business decisions. Risk can be incorporated by stochastic simulations, for example of yield and the exchange rate. In other words, instead of a single deterministic projection, results are presented in the form of probability distributions. Introducing these stochastic analyses will be the next step in making the model even more useful to industry and government. Other future research initiatives also include integrating this model into a larger horticultural model to better simulate the allocation of land to different long-term commodities.

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