AgriRisk: Bayesian Network modelling, scenario modelling and synthesis report

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Reflecting Society

March 15th, 2018

Risk Proofing Nova Scotia Agriculture: A Risk Assessment System Pilot (AgriRisk)

Nova Scotia Federation of Agriculture would like to recognize the collaborative relationships that exist among Agriculture and Agri-Food Canada and the Nova Scotia Departments of Agriculture and Environment.

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Introduction

This document presents a brief synthesis of key analyses of risk undertaken with the models developed for AgriRisk. The models are used to explore risks as identified by stakeholders at the start of the AgriRisk project and some of those identified at the scenarios workshops in February / March 2018. Not all identified risks can be addressed with the models and the intention is not to exhaustively explore all risks but rather to demonstrate the use of the BN models to explore risk in the grape and wine value chains of Nova Scotia. The models themselves are described in a companion report[1] and hence are not described here. The basic grower model used throughout this report is shown in Figure 1 below. The models are not perfect. The reader needs to bear in mind that all the analyses in this and other reports are contingent on the models and data used. As has been identified in the report on the models themselves there are considerable uncertainties associated with yield and price data: two fundamental building blocks of many of the analyses described in this report.

In the next section of the report an overview of the risks identified at the start of the project and then explored in the scenarios workshops[2] is presented. Thereafter the analyses for specific risks are shown and in the final section key opportunities and challenges presented in using the AgriRisk models for risk assessments are offered.

Risk overview

In the AgriRisk project risk has been treated as a subjective assessment of **opportunity** or **loss** due to some condition or event. At a very broad level risk is the probability of an outcome given an event. Almost always a value will be associated with different outcome states: some states are preferred more than others. More profit is usually preferred to less. Less disease is usually preferred to more. Different people at different points in the value chain or at different times will assess the risks differently and respond differently to risk: they will often have different orientations to risk and very often individuals differ in their valuation of outcomes (Sorrentino, Hewitt, & Rasoknott, 1992).

At the start of the AgriRisk project stakeholders were asked to identify what risks they were concerned with. The list of risks that were identified are shown in Table 1 below. A selection of these as well as the scenarios discussed in the scenarios workshops[3] will be used to highlight the risk analyses capabilities of the BN models.

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[1] Lynam, Timothy, 2018. AgriRisk: Bayesian Network models. Data, analyses, and models. Submitted to NSFA, March 2018.

[2] See report on these workshops for the scenarios and responses from industry: Lynam T., Flannery, M., Burkhart, N. and J. Graham, 2018. AgriRisk: Grape and wine value chain risk scenarios workshop report. Submitted to NSFA, March 2018.

[3] The three scenarios were as follows: i) Reliable information suggests demand for Nova Scotia wine is flattening as is demand for wine in general; ii) The climate of Nova Scotia is changing, warming with fewer frost free days, a

The assessment of risk starts with grower profitability in the next section. This is followed by an examination of risks associated of wineries producing what people want.

Table 1. Risk concerns identified by AgriRisk stakeholders in March 2017.

Growers	Wineries	Distribution	Consumption
Profitability	Wineries producing / doing something that damages consumer confidence or reputation	Supply & demand risk	Demographics and the potential for shifts in consumer tastes in the future
Weather and sites	Producing what people want to drink	World trade agreements	Younger generation drinking styles
Education, knowledge and feedback	Higher production costs relative other provinces	Consumer behaviour / consumer trends	
Managing disease	Free trade agreements	Inter-provincial border protections	
Extreme weather events (frost, hurricane events, polar vortex)			
Demographics of growers (age)			
Unforeseen pests (viruses, insects) developing			

Profitability

The basic grower model and the grower comparison models were used for analyses presented in this section (Figure 1). Profitability is explored as a function of two dimensions: varietal selection and vineyard size. One version of the grower model was developed as a decision model that maximised profit as a function of variety. A second version was developed as a decision model to maximise the minimum profit. The base grower model (Figure 1) was used to compare profitability across vineyard size and varietal selection choices. The profit maximising model identified Seyval Blanc as the profit maximising variety to grow and Riesling as the loss

longer and warmer growing season and fewer very cold days (<-23°C); iii) Reliable information suggests that quite soon supply could exceed demand for Nova Scotia wines.

minimising variety to grow. These differences are likely due to combinations of the magnitude and variability in yield and price for each of the varieties.

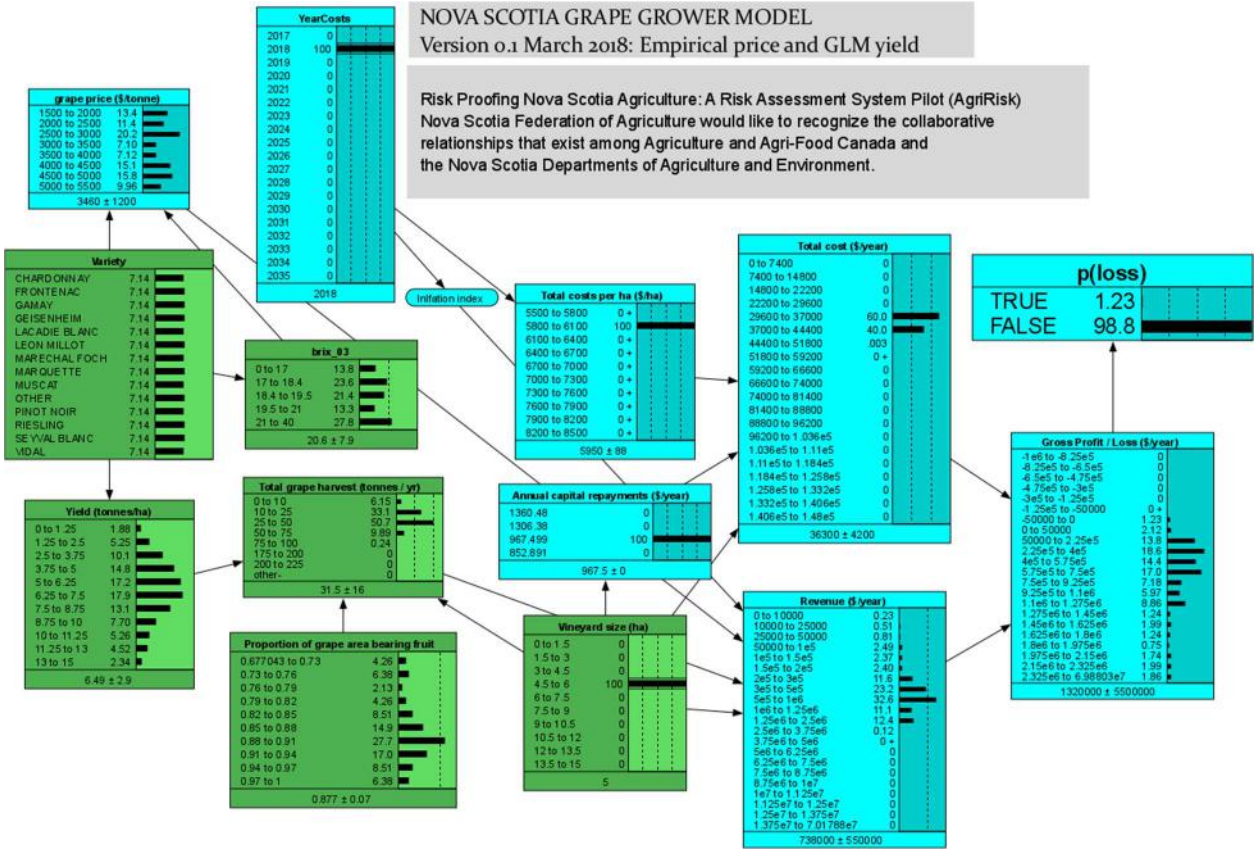

Figure 1. Overview image of March 2018 version 0.1 BN model of grape growing based on empirical data for price and yield distributions. Blue nodes are associated with the economic components of the model and green the grape growing components. See report for details.

Different combinations of varieties grown in any vineyard will therefore, clearly have notable impacts on profitability. We set up two growers in the grower comparison model with identical conditions except one (grower 1) had 75% of their vineyard under L'Acadie Blanc and 25% under Pinot Noir[4] and the second (grower 2) had 100% of their vineyard under Chardonnay. In terms of profitability grower 1 outperformed grower 2 by a considerable margin for 2, 5 and 10-hectare vineyards (Figure 2, Figure 3). The same analyses were conducted for the same growers with 10 hectares each of vineyards and the resulting probability of a loss for grower 1 was 0.03 and for grower 2, 0.08, 2.54 times as high. Grower 2's probability of making a loss was between 1.75 and 2.5 times as high as that of grower 1.

[4] This was one of the scenarios suggested by stakeholders in the scenarios workshops.

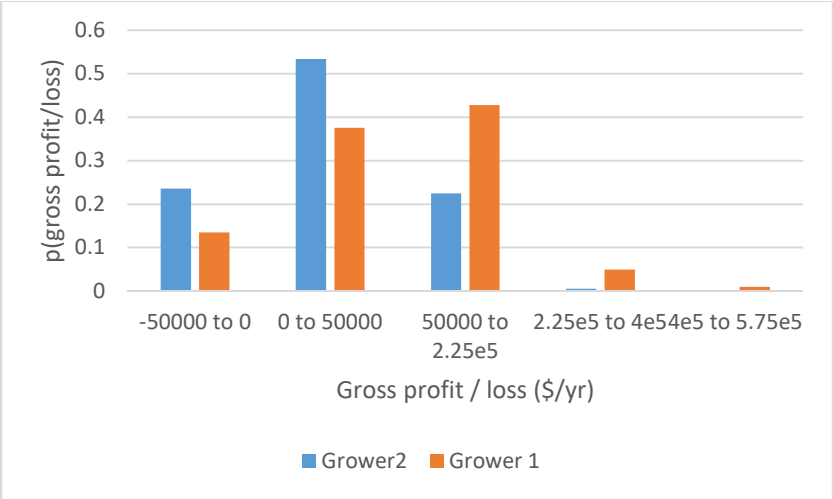

Figure 2. Differences in distribution of gross profit / loss ($/year) for two growers. Both have 2 ha of vineyards and the same yield, revenue and costs functions. They differ in the varieties they have planted. Grower 1 has 75% L'Acadie Blanc and 25% Pinot Noir and grower 2 has 100% Chardonnay. Grower 1 probability of a loss was 0.135 whilst that of grower 2 was 0.236, 1.75 times as high. Source: AgriRisk, Grower comparison model v0.1, March 2018.

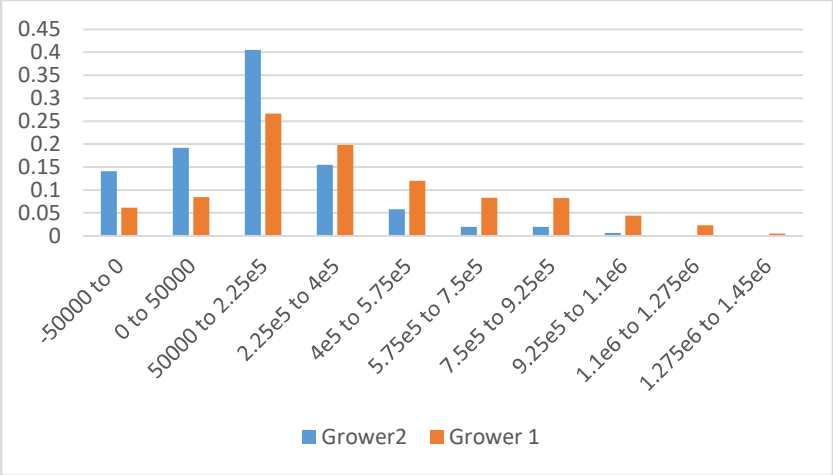

Figure 3. Differences in distribution of gross profit / loss ($/year) for two growers. Both have 5 ha of vineyards and the same yield, revenue and costs functions. They differ in the varieties they have planted. Grower 1 has 75% L'Acadie Blanc and 25% Pinot Noir and grower 2 has 100% Chardonnay. Grower 1 probability of a loss was 0.06 whilst that for grower 2 was 0.14 ~ 2.33 times as high. Source: AgriRisk, Grower comparison model v0.1, March 2018.

Across all varieties the probability of loss decreased exponentially as a function of increasing vineyard size (Figure 4). The probability of loss did not get to zero for the vineyard areas tested in the grower model (0.1 to 15ha) but different varieties had loss probability profiles across vineyard areas. We have to be cautious with these results of course because profit is not the only criteria for evaluation growers might use. Earlier I discussed the loss minimisation model: some growers might seek to minimise the variance in profit or to maximise the minimum profit. There are other (lifestyle) aspects of varietal and vineyard size selection as well as the requirement to produce grapes that wineries want. All these factors need to be taken into consideration when exploring so-called optimal solutions.

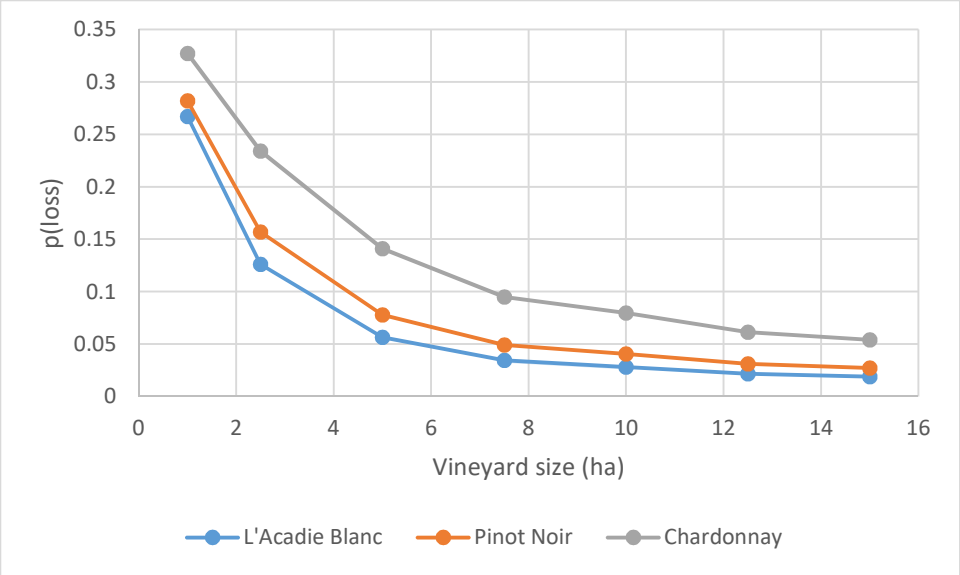

Figure 4. Probability of making a loss for vineyards of various sizes that had 100% of their areas planted to either L'Acadie Blanc, Pinot Noir or Chardonnay. Source: AgriRisk, Grower comparison model v0.1, March 2018.

Using the simple winery version of the model with two growers we can begin to explore the risk spreading across growers and wineries. We set up two growers each with 5ha of vines in full production (one may be the winery itself); one had 100% of their vineyard under L'Acadie Blanc whilst the other had 60% under Chardonnay, 20% under L'Acadie Blanc and 20% under Pinot Noir. Each grew these grapes to sell to the winery which made these three as single varietal wines. The first grower (100% L'Acadie) had about a 13% chance of making a loss whilst the second had a 20% chance of making a loss. Grower 1 makes a gross profit of about $92,000 whilst grower 2 makes a gross profit of about $57,000. The winery grosses about $430,000 through selling everything to NSLC (9500 ltrs L'Acadie; 1600 ltrs Pinot Noir and 4620 ltrs of Chardonnay). Assuming that the winery needs the inputs from both growers to maintain the diversity of products it can market, should there be a risk spreading agreement among them to reduce the risk of loss grower 2 faces?

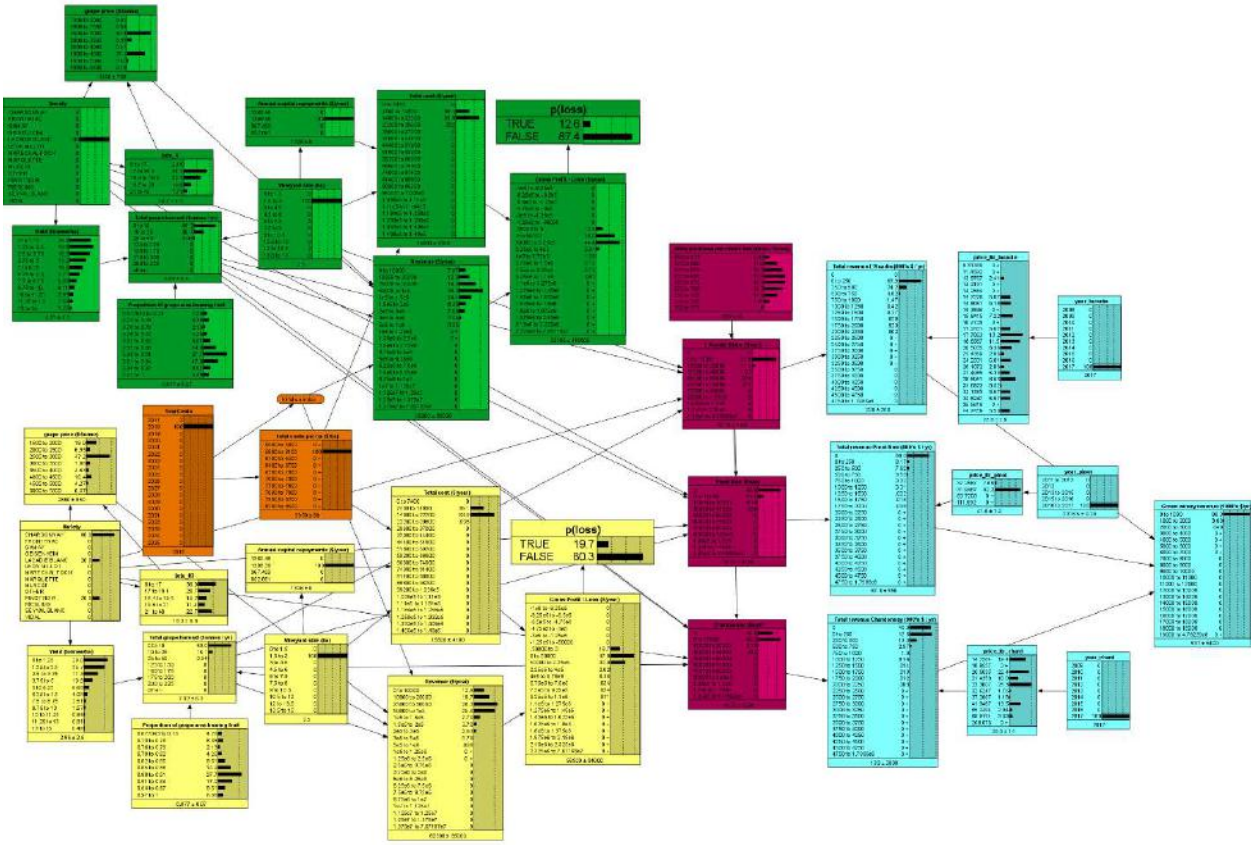

Figure 5. Simple winery model with two growers for an examination of risk spreading across the value chain. Grower 1 (top, green nodes) has 100% L'Acadie Blanc on 5 ha. Grower 2 (bottom, yellow) has 60% Chardonnay, 20% L'Acadie Blanc and 20% Pinot Noir. Source: AgriRisk, Winery model v0.1, March 2018.

Insights on profitability risk

From the analyses conducted in relation to risks associated with grower profitability some key risk related insights are apparent:

- The selection of varieties to grow is an important source of uncertainty and risk to profitability. This is particularly so for small vineyards where the costs of capital repayments can be proportionately large;
- The probability of making a loss decreases non-linearly with increasing vineyard size. Whilst there is still some small level of risk with the larger vineyards it is only a small fraction of that experienced by small vineyards. One-hectare vineyards are between 6 and 14 times more likely to experience a loss compared to a 15-ha vineyard;
- An important question that the Nova Scotia grape and wine industry may need to address is who absorbs the risk?
- At the scenarios workshops the requirement for effective communication between growers and wineries was highlighted. Given that it can take 3 to 5 years to bring a new wine to market it appears of significant importance for growers and wineries to develop

strategic plans that support the winery achieving its market objectives whilst ensuring growers can respond in a timely manner to requests from the wineries for changes in grape type or quality.

Wineries producing what people want

In the scenarios workshops participants were presented with the following scenario and asked to respond as an industry:

> *WANS gets reliable information that historical patterns of wine sales are changing, and this trend is set to continue.*

Evidence was presented to participants in two parts: the first comprised two graphs showing global trends of declining per capita wine consumption; the second comprised analyses of NSLC data showing a likely plateau in per capita wine sales[5]. In response to this scenario participants identified a) focusing on premium quality wines; and b) concentrating production on Tidal Bay and sparkling wines as key strategies to mitigate the risk of flattening consumption.

Both of these strategies look plausible as will be discussed below.

Focus on sparking and Tidal Bay

Based on NSLC sales data, we look at sales of sparking wine and Tidal bay relative to other Nova Scotia wines. Whilst the total volume of sales of Nova Scotia wine through NSLC[6] does seem to be flattening out the sales of Tidal Bay and sparkling wines have increased quite dramatically over the past 5 years (Figure 6, Figure 7). Tidal Bay sales appear to be increasing linearly at about 11,000 ltrs per year since 2012_13 financial year whilst sparkling wine sales have increased by over 2000 ltrs per year since 2014_15 financial year (Figure 6, Figure 7).

[5] See the Scenarios report cited in footnote 2 above.
[6] We did not have farm gate data available to enable exploration of this trend inclusive of farm gate sales.

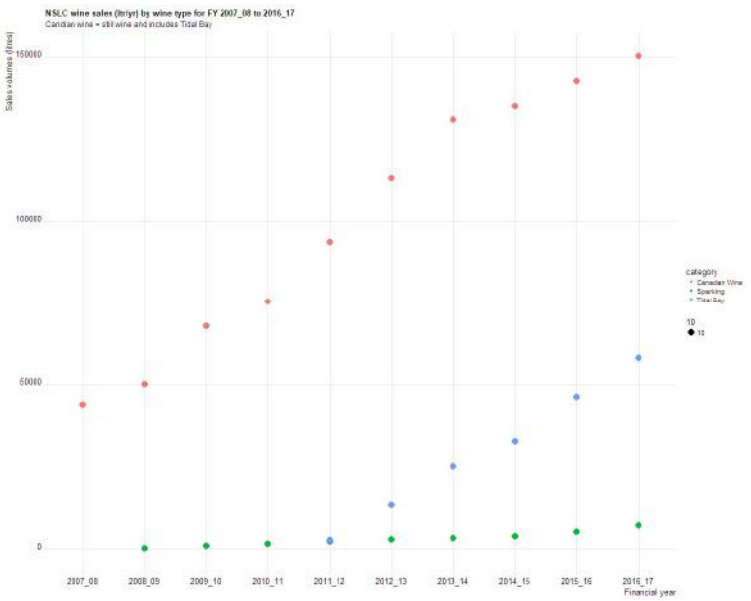

Figure 6. Sales trends for Nova Scotia still wine (Canadian wine), Tidal Bay and sparkling wine based on NSLC sales data. Source: AgriRisk analyses of NSLC, annual sales data.

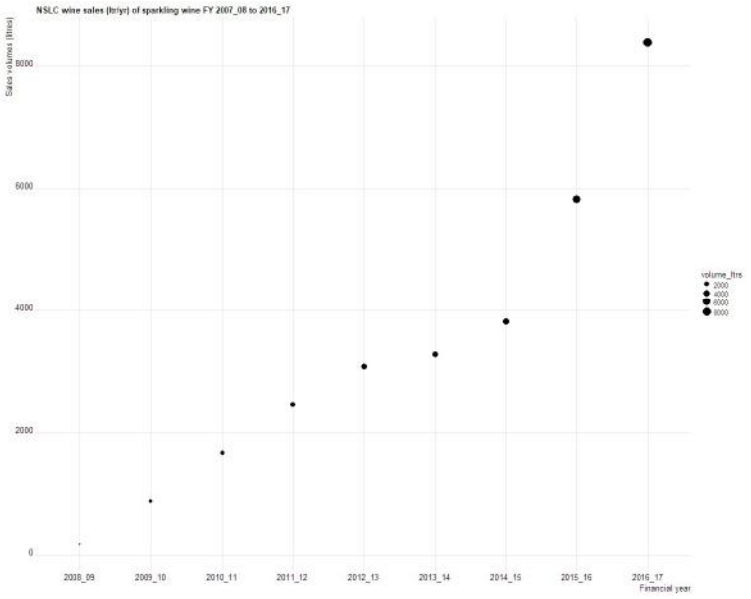

Figure 7. NSLC annual sales volume (litres per year) of sparking wine. Source: NSLC annual sales data.

As there does not appear to be any slowing down of the sales volume of Tidal Bay or sparking wine the response strategy of focusing on these two varieties seems to be sensible. It does mean however, sustaining that level of sales growth of Tidal Bay would require about 3.5 to 4 hectares

of the dominant Tidal Bay varieties to be brought into production each year[7]. This seems entirely plausible as in 2016 there were reported to be 49 hectares of L'Acadie Blanc and a total of 77 hectares of Tidal Bay dominant varieties[8] ~ more than enough to supply the 146,000 litres per year of Tidal Bay that projecting current sales trends to 2025 suggest will be the annual sales at that time.

Focusing on premium wine

The second strategic element, of focusing on premium wines also seems plausible. Using the NSLC annual sales data we can see that Nova Scotia wines have steadily been increasing their dominant price points[9] since the 2007_08 financial years (Figure 8). Nova Scotia wines have become the dominant sales items in the $25 to $35 per litre categories. It is not clear however, whether this trend of increasing prices can continue. The price trends appear to have stabilised over the past two financial years. But it certainly seems plausible and sensible for the Nova Scotia wine industry to focus on premium wines and concentrate sales in the higher price (and assumedly quality) categories.

[7] Tidal Bay is a blend of several dominant varieties (L'Acadie, Seyval, Vidal and Geisenheim 318) which must make up a majority of the grapes and secondary varieties. WANS Tidal Bay Standards, 2015.
[8] AAFC Mapping / Site Assessment report, 2016.
[9] We assume here that higher price is associated with better quality.

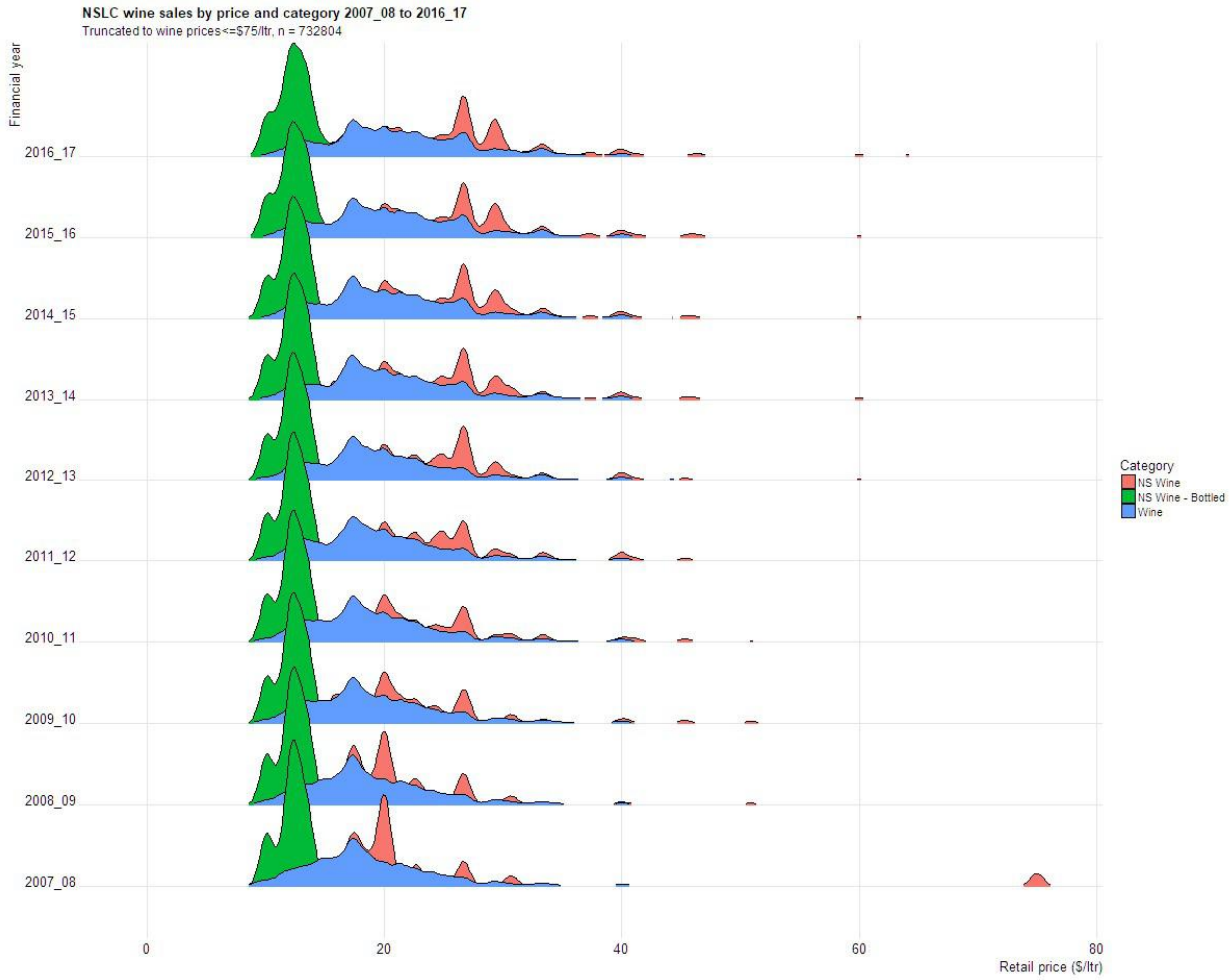

Figure 8. Trends in the sales of Nova Scotia wine (NS Wine), Nova Scotia bottled wine and imported wine by retail price for each financial year 2007_08 to 2016_17. Source: AgriRisk analyses of NSLC sales data.

Insights on wineries producing what people want risk

The following insights are evident given the analyses presented above:

- Wineries in Nova Scotia appear adept at producing what people want. Recent quite dramatic shifts in sales patterns are clear indication that wine makers can and do adjust their production practices to meet changes in consumer demands;
- The suggested strategies of focusing on Tidal Bay, sparkling wines and premium wines in response to flattening market demand seems sensible and plausible. The large unknown in that set of strategies is how big the markets for those products are and how sustainable those consumer taste shifts are[10];

[10] This issue is addressed in the Supply / Demand risk section of the report.

- One of the key risks that wineries face in strategizing about market share and position is the risk of a reduction in the preferential markup that Nova Scotia wines receive from NSLC.

Supply / demand risk

For analyse of supply / demand risk the AgriRisk Integrated industry model v0.1 was used. This model computes the total grape wine supply as a simple multiplication of uncertain variables: a) the area under grapes; b) times the yield for each variety (where varieties occupy proportions of the total area); c) times the proportion of area believed to be producing; and d) the amount of wine (ltrs) produced per tonne of grapes. Also computed is the ratio of this supply to demand where demand is: a) the per capita consumption of Nova Scotia wine estimated from NSLC data; divided by b) one minus the proportion of wine production believed sold at farm gate (to account for farm gate sales in per capita consumption estimates); times c) the population of Nova Scotia. The model also accounts for Nova Scotia grape juice going into Nova Scotia bottled wine and for wine going into inventory.

To explore risks associated with over or under supply relative to demand the following four scenarios were analysed:

1) Baseline conditions set in 2018. 405 hectares of vineyards; areal distribution of varieties proportional to the survey work done by Dr Moreau from AAFC in Kentville in 2016; 10% of wine production goes into inventory; the population of Nova Scotia is set to 950,000; the proportion of Nova Scotia grapes in Nova Scotia bottled wine is set to 0.25; farm gate sales is a scaled Beta distribution with an average of 0.5; per capita consumption of Nova Scotia wine is set at 0.503 ltrs / per capita.
2) Ongoing grape expansion. The same conditions as in the baseline except the area under grapes is expanded by 5% per annum for 10 years.
3) Increased consumption. The same conditions as the ongoing grape expansion scenario except per capita consumption grows by 25% (from the baseline) to 0.63 ltrs per capita;
4) Greatly increased consumption. The same conditions as the increased consumption scenario except consumption grows by 50% (from the baseline) to 0.75 ltrs per capita.

Analyses using the integrated model need to be cognisant of the significant uncertainties in the model. The uncertainties associated with the total amount of wine produced dominate the uncertainty associated with a supply / demand imbalance (Figure 9).

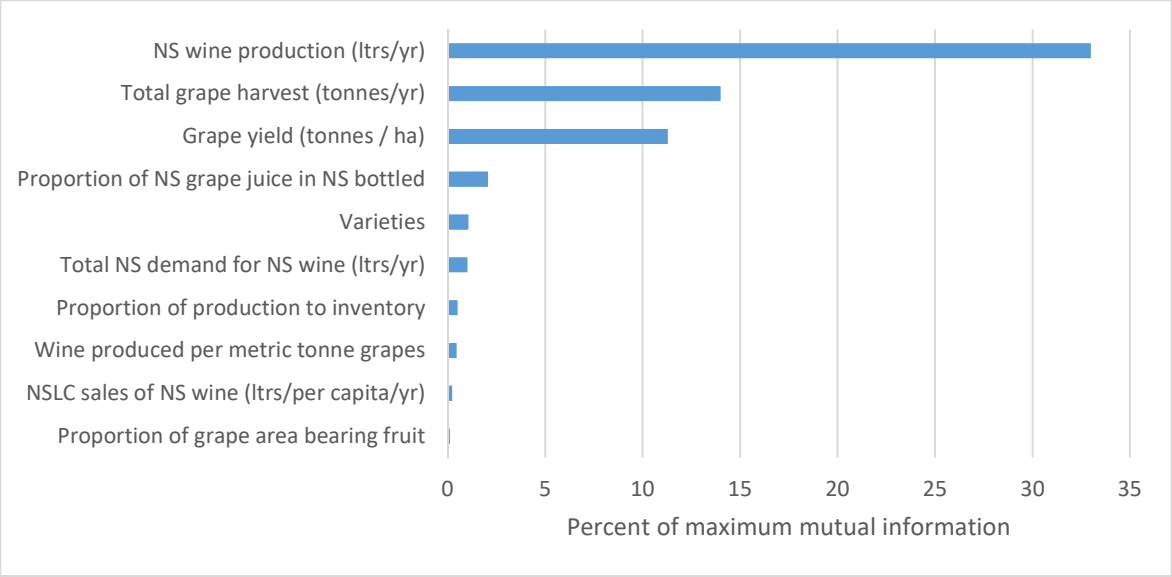

Figure 9. Results of sensitivity analysis of the integrated industry model v0.1, March 2018. Measure uses percent of maximum mutual information.

Supply / demand scenario comparisons

The probabilities of supply exceeding demand across the four scenarios range from 0.31 to 0.41 with the highest probability under the grape expansion program without increased consumption (Figure 10). These are important risks for the industry to plan for and re-assess as more data becomes available.

There are several assumptions in the model that would need to be carefully checked to ensure the most reliable data possible supports industry strategic planning:

1) The proportion of farm gate sales would have a significant impact on these results. The higher farm gate sales are as a proportion of NSLC sales the lower the probability that supply exceeds demand;
2) The proportion of Nova Scotia grape juice used in Nova Scotia bottled wine. The greater this proportion the smaller the probability that supply exceeds demand. We have almost no data on this proportion. WANS provided an estimate of 0.25 which we have used for these scenarios;
3) The yields per hectare for the grape varieties of interest are very uncertain. Much higher yields would increase the probability that supply exceeds demand.
4) How much wine wineries hold in their inventories. We have no data on this proportion other than acknowledgement from one winery that their inventory was very high. We have used a conservative value of 10% of production goes into inventory. The larger the inventory proportion the smaller the probability that supply would exceed demand. But there is a caveat: inventory is just foregone sales; at some point that inventory would need to be sold;

5) By manipulating the proportion of wine going into inventory and the proportion used in Nova Scotia bottled wine we can drive the probability that supply exceeds demand to almost zero.

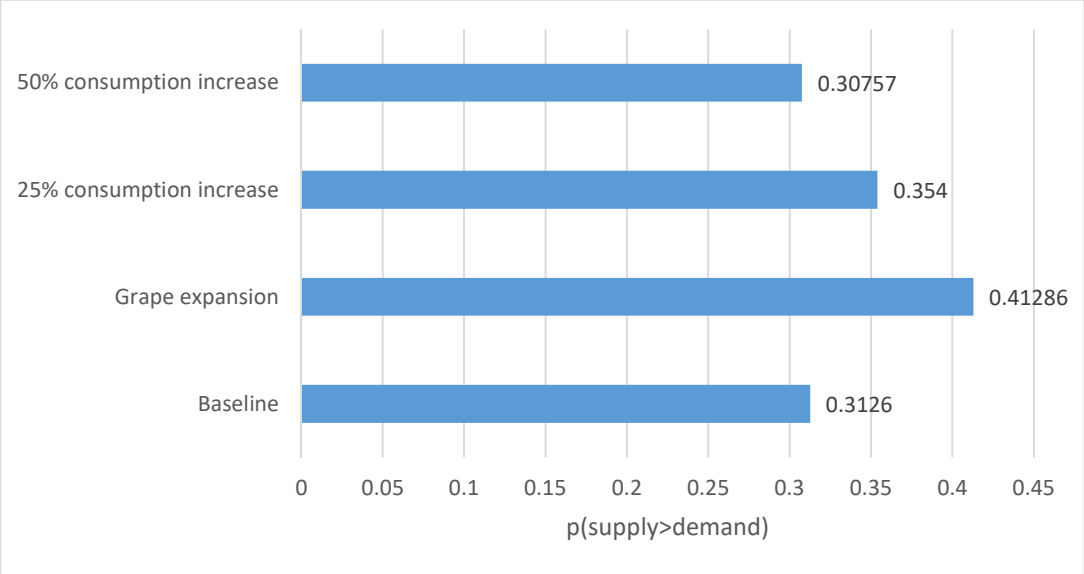

Figure 10. Results of estimating the probability of supply exceeding demand for the four scenarios. See text for scenario details.

Changes in consumer preferences or demand was an important risk identified by AgriRisk stakeholders. The current version of the integrated model does not differentiate among wines. It estimates probabilities for aggregate wine volumes. With this model the only way to explore shifts in consumer tastes is to reduce or increase demand. Based on the results of the survey of NSLC panellists on the changes in wine consumption young people tend to drink less wine than older people. We could thus use the integrated model to explore the consequences of shifting wine consumption patterns (such as a younger population drinking less wine). From the analyses presented above the implications are clear: an increased probability that supply would exceed demand.

One option the industry has suggested to absorb supply is to capture a greater proportion of the Nova Scotia wine market. At present Nova Scotia wines make up only about 5% of the total volume of wine consumed in Nova Scotia. The Nova Scotia bottled wines appear to have focused on the low value end of the wine market (Figure 8) where they dominate. Representatives of the Nova Scotia wine industry identified the need to focus on high value (premium) wines in response to the possibility of supply exceeding demand. Can the Nova Scotia wine industry capture more of the middle and high value wine markets? Our analyses suggest it may not be able to as Nova Scotia wines already account for most of the still wine sales in the middle and high value ranges (Figure 11). That leaves the lower value range which is counter to the strategy of developing more

premium wines and already dominated by Nova Scotia bottled wines. Growth in the high value wine market appears to have stagnated (Figure 8) so expansion there does not seem feasible.

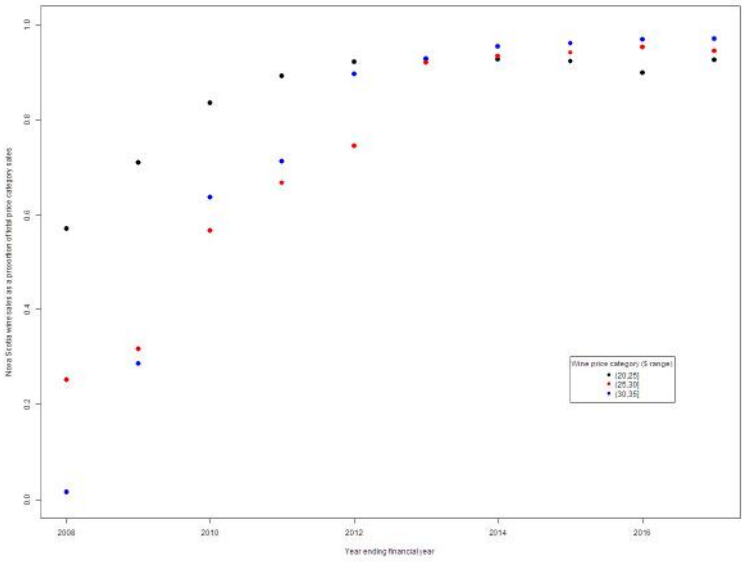

Figure 11. The proportion of the total volume of wines sales by medium and high price categories that are Nova Scotia wines. Source: AgriRisk analyses of NSLC annual sales data.

Insights on supply / demand risk

From the analyses conducted so far supply demand risk appears is significant and worthy of the industry developing strategies to mitigate these risks. Key points emerging from these analyses are as follows:

- Significant uncertainties in the production elements of the integrated BN mean estimates of supply demand imbalances are highly uncertain;
- Despite this uncertainty there appears to be a string likelihood that the supply of Nova Scotia wines could exceed demand in the near future;
- Industry representative suggestions to focus on high value wines to address this risk may not work given that Nova Scotia wines already dominate the high value categories;

Discussion and conclusions

The AgriRisk BN models provide useful tools for the exploration of a variety of risks facing the grape and wine industry of Nova Scotia. They are incomplete, imperfect but useful. In this report we have examined a series of risks that were highlighted by stakeholders in the industry. The analyses suggest that some of the risk mitigation strategies suggested by industry stakeholders may not work and there may be need to rethink these strategies in the light of what these analyses suggest.

The BN models are useful as stand-alone tools, but the analyses are strengthened through analyses of additional data sources that provide insights where the BN models either do not have the components or detail. An example is in the analysis of price trends in the Nova Scotia wine industry using NSLC data.

The weaknesses of these models have been discussed in the modelling report in footnote 1 on page 6. In relation to more in-depth analyses of risk the following however are anticipated improvements to the AgriRisk BN model suite:

- The disease component of the grower model was not available at the time of completing the baseline model and associated reports. It is likely to be available in April 2018 and this would be an important addition to the grower risk model;
- The suite of models has only limited capacity to examine risks to disaggregated wines or wine styles and yet this is a key request from growers and wineries. The current simple winery model does have this capability, in limited form. It is anticipated that this capability will be improved and then this winery model could form the basis of a more informative integrated model. There are however several technical challenges to overcome to achieve this as the current winery model is very memory intensive and needs careful redesign to make it workable as an integrated industry model.
- The grower model does not yet directly link to climate and hence climate change. There are two places where we see climate being incorporated into the model: the first is through the disease modelling; the second is through the potential expansion of plausible varieties that could be grown in Nova Scotia. Given projected changes in the cumulative GDD for Nova Scotia a range of new varieties will become options for Nova Scotia growers (as will new locations). We do not yet have the yield data or mechanism to explore yield for these varieties in Nova Scotia. This could be an important research collaboration between the AgriRisk team and viticulture researchers.
- Building a risk resilient grape and wine industry should be seen as an iterative process of building robust models to explore risks with industry stakeholders; using those models to identify risks and explore mitigation options; updating and expanding the models as new data becomes available but also as new conceptions of risk or new risks emerge. The models developed so far in the AgriRisk project are first generation models that can now be used to exploring risk and risk mitigation options with stakeholders.

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