Supporting Export Programs under Demand Uncertainty through Labelling Postponement

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Abstract

Purpose: Wineries need to support an increasing variety of SKUs to fulfill demand across sales channels. Postponing labelling can be used to mitigate mismatching supplies to demands. However this practice increases operational complexity, so it should be used only when its advantages outweigh the costs. This paper investigates the conditions that make postponement preferable to direct production.

Methodology: An unnamed Chilean winery has provided forecasts, production data and operational policies. From this data two models are constructed: one that permits production with immediate labelling, and the other that stores inventory as unlabelled bottles, mandating a secondary labelling. We capture different planning environments by running both models while varying forecast accuracy, planning horizon length, and capacity tightness. Results are measured via performance metrics based on shortages, inventory levels and setups.

Findings: Postponed production outperforms direct production when capacity is tight. Conversely, when production line capacity is only loosely constrained, postponement loses most advantages over direct production, save for when forecasts are highly inaccurate and longer *horizons are used. Results are mixed when capacity is moderately constrained, but postponement's advantages increase with longer planning horizons or less accurate forecasts.*

Practical Implications: In order to keep costs low and service levels high, export-focused wineries may need to add postponement to their toolbox. As postponement incurs additional handling costs, saavy operations managers should first consider their winery's planning environment. The optimal postponment strategy may change throughout the year as conditions shift.

Key Words: Postponement, Export Management, Forecasting, Production Planning

1 INTRODUCTION

Matching supplies to wine demand is growing more challenging. With increasing reliance on export programs and private label brands, wineries must manage more sales channels. Products destined for different sales channels or international markets may contain the same wine but cannot be treated as substitutes. In particular labels are often printed in different languages and may satisfy country-specific regulations. This product proliferation leads to higher inventory levels and more setups, in turn increasing operational costs. Furthermore, product misallocation is more likely, especially as wine production follows a yearly cycle, with demand both highly seasonal and prone to inaccurate forecasts.

Two different operational strategies can be used to meet demand: make-to-order (MTO) and make-to-stock (MTS). Applying MTO in the wine industry requires some level of production decoupling: for export-focused wineries this falls naturally at postponing labelling until the client, market, and order size is known. As Soman et al (2004) note, the large number of setups required to support a pure MTO strategy for a highly diversified product portfolio may impact order performance measures such as average response time and average order delay. Yet a pure MTS strategy may result in lower fill rates due to order uncertainty.

Other research explores tradeoffs between MTO and MTS strategies in the food (Soman et al, 2004) and wine (Cholette, 2009 and Garcia et al, 2012) industry. We must first define *Postponemen:* the purposeful delay in differentiating processes or activities until more information about customer orders is available (Van Hoek 2001). Postponement in the wine industry can take many forms, such as delaying blending of component varietals, leaving wine in tanks longer, or leaving bottled wines unlabled until demands are better known (Cholette 2009). Van Hoek (1997) anticipates the growing bulk wine market in a case study where wine is exported in bladders and bottled at the local market. However, bottled wines command higher prices, and many wineries export single varietals in a standard bottle, so the natural decoupling point is before labelling. While Cholette (2009) quantifies how postponing can benefit a winery, the author's longer-term modeling framework does not capture important operational nuances, such as batch bottling, production capacity and changeovers. Postponement can reduce inventory carrying costs and lost sales but may increase processing expenses due to the loss in economies of scale (Zinn and Bowersox, 1988).

Does postponement live up to its hype when the operational constraints are taken into account and setup costs are explicitly accounted for? We attempt to answer this question. We consider the operations of a large, export-focused Chilean winery, first presenting an overview of the operational complexities that a wine decision maker must consider. We create two mixed integer linear programming (MILP) models that differ in the kind of inventory they can keep.

Both models capture the problem of capacitated lot-sizing with setup times. We assess the performance –in terms of inventory levels, lost sales, and setup costs– of delayed product differentiation under different planning environments. The main contribution of this paper is that we demonstrate how capacity tightness, horizon length, and forecast inaccuracy affects the relative performance of both models, and thus the comparative advantage of using postponement.

The rest of this paper is organized as follows: in Section 2 we document the relevant winery operations to be considered. Section 3 presents the wine production planning models, the parameters that are varied, and the metrics for success. In Section 4 we summarize the findings from our computational experiments and their potential managerial implications. We conclude with limitations of the study and suggest directions for future research.

2 Overview of winery production and fulfillment operations

Although wine production is a long process that starts with grape cultivation and continues with harvest, fermentation, and other activities under control of oenologists, we concern ourselves only with the bottling and labelling processes shown in Figure 1. Most Chilean wineries sell their production Free on Board, which means that the buyer arranges transportation from the port to its final destination. Transportation from winery to the port is comparatively easy since the ports of Valparaiso and San Antonio are close to Chile's wine regions. However, the wineries must be able to bottle and label the wines ordered by the clients and have them ready in time to be transported to and loaded on the ship specified by the buyer before it sails on. When a winery exports to different clients worldwide, making the stack date for all the products ordered by a particular client can be challenging.

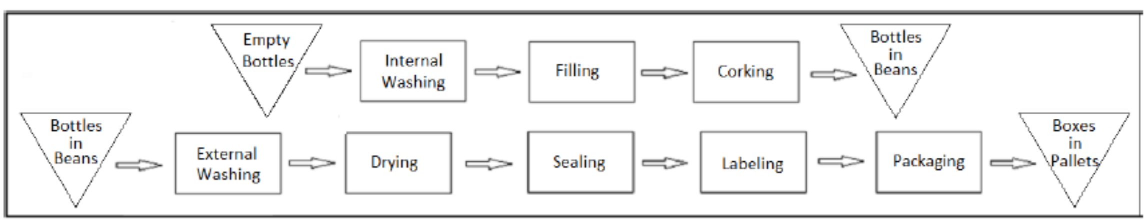

Figure 1: Bottling and labeling activities. Source: Arcos, 2004.

The critical activities, which usually determine the capacity of the line, are the bottle filling and the labeling activities. Processing speeds of bottling lines tend to be greater than the processing speed of the labeling, so when the lines work coupled the throughput of the line is usually determined by the labeling activity. Most bottling and labeling lines are highly automated and can run at a very high speed, but they require long setups when changing the product format or the wine being bottled. When the wine changes, both the intermediate bottling tank and the filling device on the bottling line must go through a cleaning process that removes all traces of the wine that was being filled. The length of the setup is sequence dependent on the type of wine and the quality of the wine. The time required to switch from red wine, to white wine is much longer than the time for the opposite switch. Also, switching from a regular wine to a premium wine takes longer than the converse, since mixing regular wine in with a premium wine is a worse error than getting some premium wine in a regular wine. Typical changeover times are almost two hours when going from a red to white wine, while going from white wine to a red one takes about one hour. The labeling process, on the other hand, is more agile than the bottling one since setup times are much shorter and are not sequence dependent. For example, changing the label roll takes at most half an hour.

3 METHODOLOGY

We capture the winery's production planning problem with two mixed integer linear programming (MILP) models that differ by whether bottled inventory is stored unlabeled as work-in-progress (WIP) or labeled as finished goods. While in practice wineries may hold both unlabeled and labeled bottles, our research objective is to explore the impacts of labelling postpontment on production planning performance. The full mathematical formulations are presented in Varas (2016); for brevity we summarize their salient aspects.

Model Dimensions	
I	Types of wine (2 types)
J	Labels (3 labels)
K	Production Lines (2 lines)
T	Time period (20 + HL weeks)
Environmental factors	
Horizen Length (HL): 3,4,5 weeks	
Production Capacity (PC): loose, moderate, tight	
Forecast Accuracy (FA): varying from relatively accurate to highly inaccurate	
Key Parameters	
Demand D_{ijt}	Uniform distribution over interval [.75 to 1.25] for each finished good ij and time t
Forecast $FD^{t}_{ijt'}$	Forecast made in t for finished good ij in period t'. Less erroneous as t' becomes closer to t and with exogenous input (FA)
Performance Measures	
Shortage Level (SL)	Shortfall in demand for all finished goods that week not satisfied through production or from inventory, , averaged across all weeks and instances.
Inventory Level (IL)	Number of bottles, either labelled or unlabeled, stored at the winery that week, averaged across all weeks and instances.
Setups (SU)	Number of setups that occurred for bottling and/or labelling in a week, averaged across all weeks and instances.

Table 1: Model Setup Summary

3.1 Rolling horizon framework

Production planners often deal with forecast uncertainties using a rolling horizon framework (Chand et al, 2002). Illustrated in Figure 2, this framework requires setting the planning horizon length (HL), the frozen interval, and the replanning periodicity (Xie et al, 2003). The frozen interval is the subset of periods within the planning horizon for which the production plans are implemented according to the original schedule. The replanning periodicity (RP) is the numbers of periods between information updates and replanning production activities for the non-frozen periods. These parameters must be carefully set due to the trade-offs involved. Horizon lengths vary according to the order acceptance policy of the sales department; we will test the effects of setting the horizon length at 3, 4 and 5 weeks. A longer planning horizon may improve effective use of resources, such as manpower through shift management, but adds more uncertainty to the manufacturing process due to more error-prone forecasts. A higher replanning periodicity (less frequent replanning) reduces the planning *nervousness*, simplifying supplying decisions, but reduce manufacturing flexibility, the ability to react to order changes (Gupta and Goyal, 1989). We assume that the winery typically makes the production planning decisions on a weekly basis: thus both the frozen interval and the RP will be 1 week. For each run we roll the model forward 20 times.

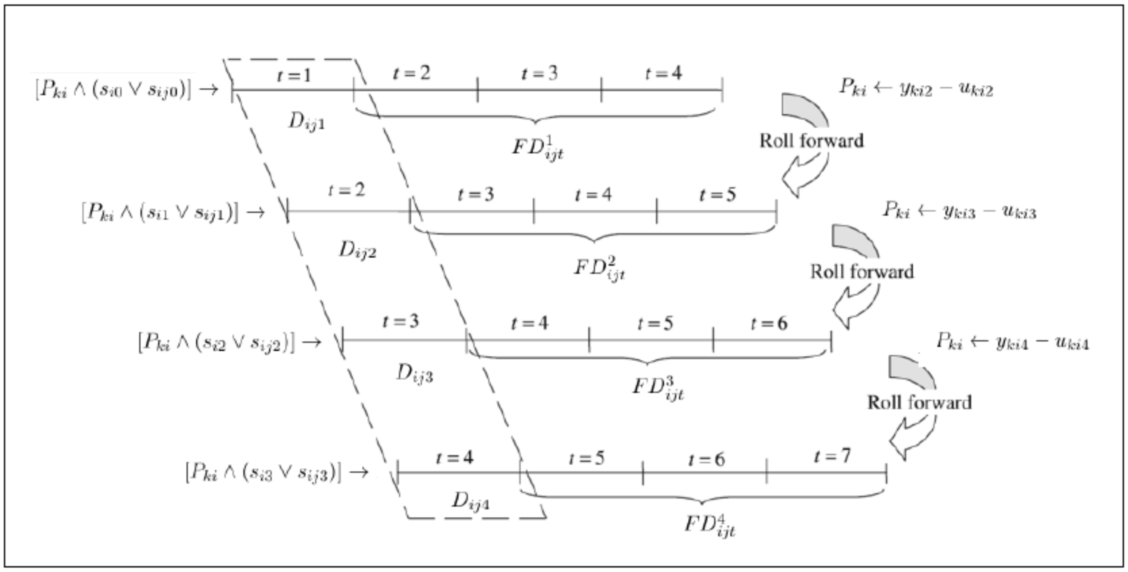

Figure 2: Rolling horizon framework with a RP of one period and a HL of four periods. Note that D_{ijt} refers to the actual demand in period t, whereas $FD^{t}_{ijt'}$ refers to the forecast made in t for the certain demand in period t', with t < t'. Source: Asad and Demirli, 2010.

3.2 Demand Variability and Forecast Inaccuracy

Although wine typically exhibits seasonality, we assume demand for the finished goods over all periods is uniformly distributed. Forecast inaccuracy is incorporated via a parameter that multiplies the difference between a period's forecast and the actual demand, much as is done in Clark (2005). This parameter increases the further out demand is forecasted and is also tweaked exogenously with a Forecast Accuracy (FA) factor to mimic different production environments. We run both models for 60 different levels of this factor, defining three ordinal groupings of forecasts: relatively accurate, moderately inaccurate and highly inaccurate.

3.3 Decisions and Constraints

The main difference between the models is that the postponement model permits intermediate inventories to be generated by pulling tanked wine from the tanks and bottling it unlabeled. Conversely, the direct production model allows for wine to be bottled and labeled either to meet demand in that period or to be stored to meet anticipated future demand. Both models allow the lot size for a particular run to be determined endogenously. For example, larger lot sizes will increase inventory levels (IL) but reduce costs associates with setups (SU).

Production decisions must respect operational constraints on tank usage and production line capacity. Production occurs one of two labeling and bottling lines, and the throughput of these lines is set so that production capacity (PC) will be either relatively loose, moderate or tight with respect to average demand. If demand is unable to be met that week, a shortage (SL) is incurred.

3.4 Performance Measures and Objective Function

We consider three performance measures, where lower values are better. The average inventory level (IL) represents the number of bottles, either labelled or unlabeled, stored at the winery that week. Shortage levels (SL) are defined as any shortfall in demand from that week that was not satisfied through production or from inventory. Setups (SU) indicate the average number of setups that occurred for bottling or labelling activities that week. Use of labelling postponement means that as bottles must be run twice through the line, more setups will occur than with direct production, assuming similar lot sizes. Each of the models employs a weighted objective function to minimize the combination of these three measures. The weights are set to reflect the studied winery's preferences: shortages are the most pressing concern, while setup costs are typically less important. However, these weights have been calibrated so that no one metric will automatically dominate the other two.

4 FINDINGS AND MANAGERIAL IMPLICATIONS

We experiment with different planning environments by varying three factors: horizon length, forecast accuracy, and capacity tightness. These factors are important to consider as capacities vary by winery or even by season within the same winery, as can forecast accuracy and horizon length. We solve the two models for 100 instances of all such possible combinations, examining the weighted mix of resultant performance metrics. For brevity and simplicity, we present the comparative findings in Table 2, indicating whether the results are statistically significant ($p < .05$) and if so, when postponed production is preferable to direct production.

Postponed production outperforms direct production when capacity is tight, most notably due to service level failures due to production's inability to fulfill orders ontime. The superiority of postponed production is even more pronounced when forecast are less accuracy or planning horizons are longer. Conversely, when production line capacity is only loosely constrained, postponement loses most advantages over direct production, save for when forecasts are highly inaccurate and longer horizons are used. Results are mixed when capacity is moderately constrained, but postponement's advantages increase with longer planning horizons longer or less accurate forecasts.

Thus, before deciding whether to use postponement, winery planners would need to understand how accurate their forecasts are and how busy their productions lines are likely to be. Given that demand is highly seasonal, forecast accuracy and capacity usage may vary throughout the year. One managerial implication is that savvy operators could shift production strategies, postponing in times when production lines are likely to be highly constrained and orders less certain, then switching back to direct production in quieter or more certain times. These findings also suggest that winery operations managers will benefit from working more closely with their sales and marketing colleagues, as improvements to forecast accuracy or even just knowing when forecasts are more likely to be more accurate may shift the ideal operational strategy.

Forecast Accuracy	Horizon Length	Production Capacity		
		Loose	Moderate	Tight
Relatively Accurate	HL=3	*Definitely Worse*	*Definitely Worse*	**Definitely Better**
	HL=4	*Definitely Worse*	Results inconclusive	**Definitely Better**
	HL=5	Results inconclusive	Results inconclusive	**Definitely Better**
Modurately Inaccurate	HL=3	*Definitely Worse*	Results inconclusive	**Definitely Better**
	HL=4	*Definitely Worse*	**Definitely Better**	**Definitely Better**
	HL=5	Results inconclusive	**Definitely Better**	**Definitely Better**
Highly Inaccurate	HL=3	*Definitely Worse*	**Definitely Better**	**Definitely Better**
	HL=4	**Definitely Better**	**Definitely Better**	**Definitely Better**
	HL=5	**Definitely Better**	**Definitely Better**	**Definitely Better**

Table 2: Comparing Postponement to Direct Production under different environments

5 CONCLUSION

Although this work provides insights into the conditions that make postponement beneficial, some limitation must be addressed. As previously mentioned, wineries may not be operate only as make-to-stock or make-to-order but instead use a combination of both strategies (Garcia et al, 2012). Cholette (2009) shows that the optimal fraction of production postponed depends on conditions such as demand volatility. Thus, if results from our simplified analysis favor postponement over direct production, the real world solution will likely include both strategies but have more weight on postponement than in situations when our models favor direct production.

We have reduced the problem size so as to be able to solve this problem to optimality and to better illustrate fundamental results without cluttering details. However, we plan to develop heuristics that will handle the scale needed for solving the larger problems of real-world wine production planners.

As forecasts are unreliable and subject to change, solving models to optimality provides a limited benefit. Decision makers typically develop a variety of what-if analyses. Use of fix-and-relax heuristics such as espoused by Merce and Fontain (2003) should provide sufficiently good solutions for real-world problems with minimal computational burden.

Export-focused wineries will need to keep their costs low and service levels high in order to compete in the increasingly globalized wine market. Yet wineries and agribusiness producers on the whole have lagged behind other sectors such as tech and automotive (Van Hoek et al, 1998) in adopting measures such as postponement. Research such as this may serve to convince decision makers to consider postponement as an operational strategy and determine when it is more likely to be effective.

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