Live Sheep Export – A Review of the Mecardo Report

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1. Introduction

Many viewers and readers were shocked in early April 2018 by graphic vision of sheep suffering and dying on a transport ship from Australia to the Middle East. The subsequent media storm included strong calls for live sheep export to be banned. In response, the agribusiness analyst Mecardo issued a report called *Live Sheep Export – Brief Report*, in which the potential cost to the industry in Western Australia of a ban on live export is calculated to be $80 to $150 million. WA supplies the vast majority of live sheep for export from Australia and so it is the region most affected by any policy change.

The animal welfare lobby group Animals Australia approached me for advice on interpreting the Mecardo report. The terms of reference are at Appendix 1.

The Mecardo report is indeed brief – just eight unnumbered pages including the front cover. There is scant documentation in the report itself, to the extent that it would not be acceptable for academic publication in any respectable journal. Mecardo claimed that some of the key data used in the report is proprietary and difficult for them to access, so would only be revealed to me on payment of a fee of several thousand dollars. Mecardo also wanted to nominate a co-author to assist my investigations. On both counts, I told Animals Australia to say "No, thanks".

Instead, I have resorted to reverse engineering the Mecardo data from the results and the various charts in the report. This operation has been remarkably successful, as I will show. My replication of their model, based on an extract of their data from the charts, is better than often obtained when academic studies are repeated using what is purported to be the original data and model.

From this systematic unpacking of the Mecardo model and use of the replicated model to forecast the effects of a live export ban, I conclude that the Mecardo analysis is very superficial and unworthy as a guide to policy. Some specific failures:

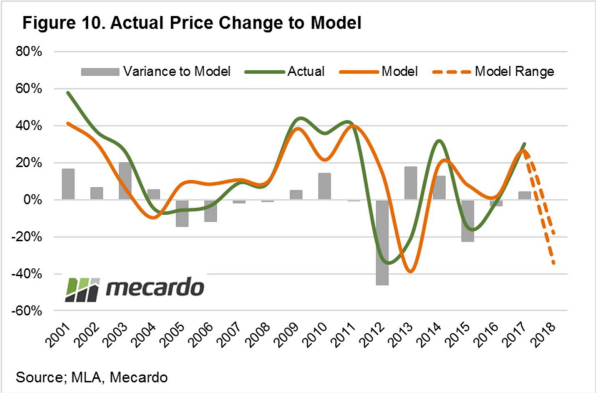
- The calculations in the report rely entirely on the correlation between two variables, without regard to the causal factors needed for policy analysis. Notable in this regard are the implausible assumption that export prices are determined solely by local supply in WA and the absence of any dynamics or other variables in the regression equation.
- The movements in the data over the historical period from which the model is estimated are very large. While there is an association of price falls in the same year as quantity increases, and *vice versa*, there is also a large residual uncertainty in any forecast based on the estimated model. The "worst-case" outcome from their model of a $150 million loss is indeed large, but it is not necessarily a loss at all when the large statistical variability is considered.
- The statistical model relates annual price changes to annual quantity changes in the same year, without any reference to earlier changes or to the levels of either variable. Thus it concentrates entirely on short-run outcomes and says nothing about the longer run. At best, the headline numbers of $80 to $150 million will represent only the one-year effect of a ban, without any consideration of what happens after that.
- The headline numbers are derived by applying the forecast per head price impact to the numbers of sheep and lambs that are currently sent to slaughter. That calculation ignores the loss in value of the sheep that are currently exported live, which might add nearly half as much again to the loss figures. But scaling up those headline numbers will simultaneously scale up the problems identified in the first three dot points above, so the resulting numbers will be larger but just as dubious.

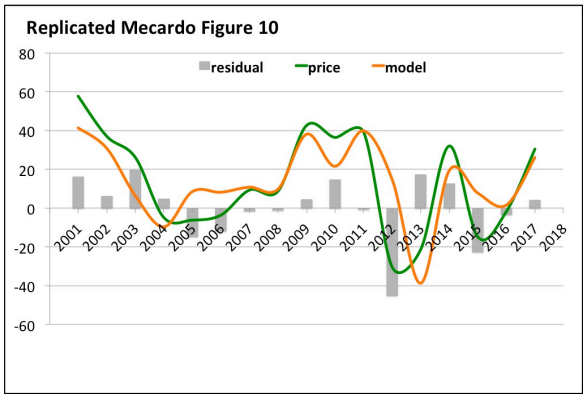
- Some of the charts in the report are mis-labelled, inverted or illusory. This indicates to me undue carelessness in preparing the report.

2. Extracting the data and replicating the model

The statistical model used for forecasting in the Mecardo report relates the annual percentage change in prices to the annual percentage change in the quantity slaughtered. I extracted the price and quantity data from Mecardo's Figure 8 by a process of photographically enlarging the chart and measuring the co-ordinates of each point. While at it, I also recorded the co-ordinates of two points on the fitted line in that chart to compare the equation of that line with my replicated model. I then arranged the data in a time series by comparison with Mecardo's Figure 9.

My extract of the Mecardo data is reported in Appendix 2 along with my replication of their model. The chart on the right below contains my results in the same format as Mecardo's Figure 10 shown on the left. The green line for *price* in my chart shows the replicated price series and corresponds to *Actual* on the Mecardo chart. The orange line *model* in my chart is the fitted or predicted values of price based on the relationship with the slaughter quantity, using my data for both of these series and my replicated model to form the predictions. This corresponds to what Mecardo calls *Model*. The bars for *residual* corresponds to what Mecardo calls the "Variance to Model", where my values are taken from my replicated data and model. All of these aspects of my results coincide with the corresponding results in the original Figure 10, thus showing that I have replicated Mecardo's data and model almost exactly.





Further confirmation that I have replicated Mecardo's data and model with high precision may be found in a comparison with the meager information that is included in the report about their model. They say the R-squared of the line in Figure 8 is 58.38%, where for my replication of their model it is 58.68%. My measurement of the line in Figure 8 gives an intercept of 12.24 and a slope of -1.089, while my replicated regression model estimates an intercept of 12.52 and a slope of -1.088. These differences produce forecasts from my model that differ from the forecasts by Mecardo's model by less than the rounding to whole numbers that characterizes the report.

It may be an unnecessary elaboration, but another indication that I have captured their data and model very closely is a comparison of the residuals from my model with the corresponding bars in the original Figure 10 (the vertical bars in the above charts). The two sets of numbers agree with a squared correlation of 99.96%.

Both of the individual coefficients in the replicated regression model are statistically significant at the conventional levels and, as reported by Mecardo, the fit is fairly good with over 58% of the price variation explained by the relationship with quantity. There is no evidence of residual serial correlation, at least as disclosed by the standard test at the first order lag.[1] The residual standard error remains large, however, with the implication that forecasts from the model will be imprecise. I discuss this latter aspect in more detail below.

3. Some errors in Mecardo's charts

While it may seem that extracting Mecardo's data and replicating their model was easily done, some inconsistencies among their Figures 8, 9 and 10 made the replication task more challenging. Assuming their Figure 10 is correct, the labels in Figure 9 must be incorrect. The green line for price in Figure 10 should correspond with the orange line for price in Figure 9. Thus it is the orange *price* line that is inverted in Figure 9, not the green *quantity* (slaughter) line as stated.

Further, in Figure 8 the labels on the axes are reversed. The vertical dimension corresponds to the *price* data in Figure 10, while the horizontal axis corresponds to the *quantity* (slaughter) data. This arrangement is opposite to what is stated.

My interpretations of the errors in Figures 8 and 9 depend on the assumption that Figure 10 is correct. The fact that I can replicate the fit and residuals of the model so closely, together with my finding the same forecast effects of their policy scenario, confirm that the model used by Mecardo for forecasting is indeed consistent with Figure 10.

These errors in reporting do not change anything in the analysis, although they do indicate a surprising degree of carelessness in preparing the report. I will consider the suitability of the model for analysis of the policy later. In the meantime I will concentrate on unpacking the policy forecasts.

4. Replicating the forecasts

The Mecardo report is not entirely transparent about the policy scenario used to obtain the headline results of a loss of between $80 and $150 million. In particular, nothing is said about the timescale over which the changes are expected to occur. The following is my reconstruction of where these numbers come from.

Mecardo "worst-case" scenario

The "worst-case" scenario assumes that, in the first year following the data record, the whole quantity of live export sheep from the base year are sent for local slaughter (where the base is 2017, the last year of the record). The historical relationship of annual price changes to slaughter changes (both in percentage terms) is used to predict the corresponding price change. Since live export is said to be 30% of the offtake in 2017, when these additional animals are sent to slaughter the slaughter quantity will be increased by a factor of $3/7$ or 43.3%. Putting this value of *slaughter* change into the

[1] There is very evident first-order serial correlation in the plot of the residuals in the above chart and in Mecardo's Figure 10. The heights of the bars clearly form a sequential track, with positive values mostly following other positives and negatives mostly following negatives. However, with only 17 data points in the series, the measurement of serial correlation is entirely undone by the one very large residual in year 2012.

model yields a forecast *price* change of minus 34.6%. This is the result described by Mecardo as the worst-case scenario where "prices decline … 35%".

The percentage decline is converted to a dollar value by some additional information given in the report. The 35% price decline of the worst-case scenario is said to be $43 per head for lamb and $35 per head for mutton, with the lamb slaughter being 45% and sheep slaughter being 25% of the total offtake. Thus the base line for average value of a slaughtered animal in 2017 is implied to be $115.

As a check, the same base line calculation applies to the best-case scenario, so it should give the same result apart from rounding errors. An 18% price decline is said to be $23 per head for lamb and $18 per head for sheep. In this case the average value of a slaughtered animal in 2017 is implied to be $117. To minimize the effects of rounding errors, we take the base line to be the average of these two deduced figures, that is $116 per head.

The annual numbers of animals involved can also be deduced from data in the report. If live exports are 1.6 million animals and constitute 30% of the offtake, then 3.7 million animals are sent to slaughter. The worst-case scenario appears to be calculated as follows: 3.7 million animals, by a 35% price fall, by an average value of $116 a head, so that is the headline loss of $150 million.

Mecardo "best-case" scenario

This scenario involves the same model and the same forecast from the model. The difference is the fall in prices is limited by the prospect of selling animals in the eastern states. The maximum price decline is the transport cost, which on the data provided reduces the price fall from 35% to 18%. The "best-case" calculation appears to be: 3.7 million animals, by an 18% price fall, by an average of $116 a head, so the headline result is a loss of $77 million, which rounds to the stated $80 million.

5. The model is not appropriate

The Mecardo report is not simply a forecast of the future but a purported analysis of the effect of a policy change. Policy analyses are necessarily about causal relationships, because they make evaluations of the kind: *if* these steps are taken, *then* this outcome will likely follow. The regression model used by Mecardo cannot be causal, because the price variable used is an export price that is largely determined in world markets. Moreover, the model omits any of the features that might help to distinguish cause-and-effect from mere correlation.

The statistical model is a simple regression of one variable on another over 17 annual observations from 2001 to 2017. The dependent variable (or response) is a composite price of sheep meat, while the single explanatory (or control) variable is the quantity of animals sent to slaughter in WA, with both variables expressed as the percentage change from the previous year.

The price variable in the report is apparently a composite price index of Mecardo's own devising that covers "WA mutton and trade lamb (in US$ terms)". It is unclear why this series was chosen, apart from a vague suggestion that most of the extra meat created by the additional slaughter might be exported. Nevertheless, this is an *export* price that is determined in world markets, and which will not depend much if at all on supply conditions in WA. In the context of the local slaughter market, this is largely an *exogenous* variable, which is inappropriate to use as the dependent variable in regression relationship.

It is possible to imagine an entirely different relationship that acknowledges export prices are largely exogenous to the local economy while giving a similar negative correlation between price and quantity. If the local slaughter quantity reacts to export opportunities with a time lag of several years needed to build up flocks, it is likely that slaughter quantities may be rising just as world prices are falling. Time lags may also be responsible for falling slaughter quantities at times when world market prices are picking up, reinforcing the observed negative correlation between changes in export price and slaughter quantity. In this alternative mechanism with reverse causality, it would be mistaken to use the simple regression of price changes on quantity changes to predict the policy effect.

I do not suggest that this alternative mechanism is the whole story (although it seems more plausible than the assumptions implicit in the Mecardo statistical model). Separating out such competing accounts of the relationship between export price and domestic quantity would require a sound economic model and an analysis of the dynamics between the variables. The Mecardo regression equation has completely independent outcomes from one period to the next, without any lags or other dynamics. There is no forward-looking behaviour by either buyers or sellers and no costs of adjusting to a new equilibrium when circumstances change. Indeed, there is no measure of time in the model and no representation of market equilibrium at all. Further, there are no other explanatory variables in the model, as typically would be used to hold constant other factors while the effects of a policy change are measured.

This naïve statistical model in the Mecardo report is unsuitable for the policy evaluation in which it is employed

6. Robustness of the forecasts

All of the calculations of potential losses depend on the forecast from the model in which a 43.3% increase in slaughter quantity leads to a 35% fall in prices. The same forecast also determines the relevance of the best-case scenario in which the losses are limited by transport costs. An important question is whether the actual response is likely to be more or less than the point forecast of a 35% fall in price.

The answer to that question depends on the standard error of the forecast, which in turn is directly dependent on the unexplained residual standard error in the estimated model. For the assumed quantity increase of 43.3% when the price fall is calculated to be 35%, the standard error of forecast is 20.4%. With a model that has 15 degrees of freedom, the 95% cut-off value is $t = 2.131$, giving a 95% confidence interval for the price fall as the range -8% to $+78\%$. Thus, to provide the customary 95% level of confidence in the forecast, the range of outcomes has to include the prospect that the losses are *twice as large* as the headline figures reported by Mecardo. At the other end of the range, possible outcomes go all the way down to where there is *no loss at all*. Even ignoring the logical matter of cause and effect, on purely statistical grounds the forecast being relied on for the policy evaluation in the report is very unreliable!

7. Other implications of the Mecardo model and forecast

Using a simple model to predict price changes from quantity changes in the same year, without any regard to the long-run outcomes, has another perverse implication. The loss that is calculated as the effect of the policy relates only to the *first year* of the assumed policy scenario. If nothing further changes, in the following year on these calculations there will be another $80-$150 million loss relative to the base year 2017. That outcome will be followed by a further $80-$150 million in the next year and in every year beyond that. The accumulated total into the future is infinite, unless the future is severely discounted!

Another dubious element of Mecardo's calculations is the loss that is calculated is applied only to the 3.7 million animals that are sent for slaughter in the base year. There is nothing to represent the loss of value in the 1.6 million animals that are sold as live export in the base year but are then added to the slaughter quantity under the assumed policy. At a first approximation[2], these animals would be equally as valuable as the local slaughter animals in the base year and suffer the same price falls due to the policy. On the Mecardo model, if the whole annual offtake of 5.3 million animals were considered, there would be potentially another $3/7$ or 43.3% to be added to the bill.

It might be tempting to escalate the Mecardo headline numbers to adjust for these omissions. That would be mistaken, because the headline numbers do not represent the cost of the policy in any meaningful way and in any case they are statistically insignificant. Scaling up meaningless and unreliable numbers will produce larger numbers, but the deficiencies will be scaled up as well.

A further problem comes from using the export price "in US$ terms". The policy question as posed by Mecardo relates to the return to WA producers. For this evaluation, prices need to be expressed in local Australian dollars, not in the international currency of the trade agreements. Perhaps the preference for the form of the price variable adopted in the analysis is revealed in the first footnote of the report: the historical correlation between local slaughter and the export price is notably higher when price is expressed in US dollars than when denominated in the local currency.

8. Conclusions

I come to the view that the Mecardo report is more a document of persuasion than an expert analysis of the cost to the industry of banning live sheep export. A proper forecast of the effects would allow for adjustments both in the quantity supplied to the market each period and the expansion of markets interstate or internationally. New markets take time to develop and would not be reflected simply in the historical year-by-year shifts in slaughter quantity and price that form the basis of this report. Even within the narrow approach adopted, the forecast is based on a statistical relationship that is inconsistent with the choice of variables. The failure to account for other variables, including lags, further removes the approach from proper policy analysis. Separately, the reported forecasts are not statistically significant, while in further complications only some of the consequences appear to be captured in the calculation.

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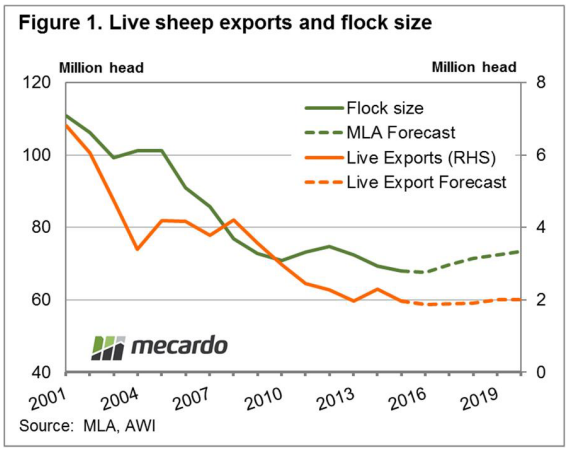
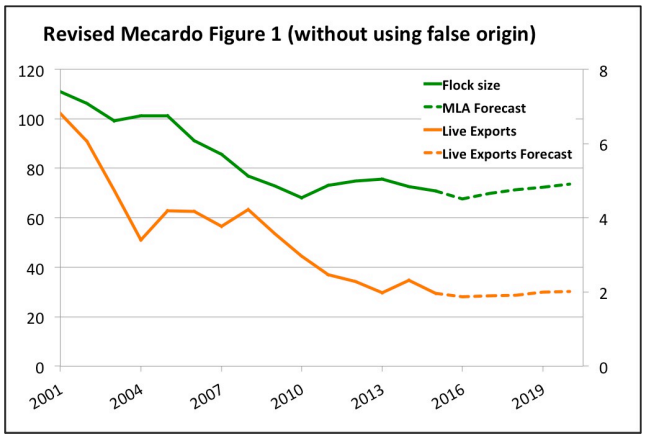
[2] This calculation may overstate the extra value slightly, because the live export mix of lambs and sheep is typically skewed to older animals, which are less valuable. On the other hand, producers are typically paid a premium for sheep going to live export, which would make the approximation more reasonable.

My negative view of the report is exacerbated by some apparent biases in reporting. An early example in the report is Figure 1 (on the left below), which is employed to support the opening sentence: "The total live export volume of sheep departing Australia has been in decline in line with the reduction in the national flock size…" What appears to be a roughly equal slope in the orange and green lines in that chart is an illusion created by the use of a false origin for the flock size scale.





Starting the scale at 40 million rather than at zero has the twin effects of both shifting down the green line so that it roughly coincides with the orange line *and* expanding the slope of the green line so it more closely resembles the slope of the orange line. The impression so created of the two slopes being "in line" hides the fact that live exports have shrunk over the period at *more than twice* the rate of the decline in the flock size. A revised chart without the false origin (on the right above) clearly shows that live exports have shrunk proportionally much more than the flock size over the period.

Appendix 1: Terms of Reference

An assessment of the appropriateness and validity of the data sets, methodologies and conclusions of the modelling and analysis conducted by Mecardo Analysis in their report entitled Live Sheep Export – Brief Report dated 20 April 2018. We seek your expert advice on the broad question:

- Can the outputs from the Mecardo report be relied upon as an accurate assessment for the development of public policy in relation to live sheep exports?

In particular, we ask you to consider these matters:

- Are the behavioural assumptions in the modelling appropriate to the question?
- Does Mecardo provide a satisfactory explanation and justification of those assumptions?
- Does the statistical model appropriately reflect those behavioural assumptions?
- Does that model appropriately reflect the time scale over which adjustments might occur in the industry?
- Is the model appropriate for forecasting future events of the kind investigated in the report?
- Are those forecasts robust and reliable?
- Are the model and forecasts used in the report in an appropriate manner to assess the policy question?

Appendix 2: Mecardo data and model

The variables *price* and *slaughter* in the table below were obtained from Figures 8 and 9 in the Mecardo report by the procedure described in the text. The columns *model* and *resid* are the model fitted values and the residuals after estimation of the model, using the data contained in the first two variables. These latter two columns can be compared with the line called "Model" and the bars "Variance to Model" in Mecardo Figure 10. The conformity is very close within the accuracy of the chart. The remaining column *sef* is the standard error of forecast. The calculations are made in Stata v.11 using the commands shown in Appendix 3.

year	*price*	*slaughter*	*model*	*resid*	*sef*
2001	57.6	-26.4	41.2	16.4	.
2002	37.0	-16.8	30.8	6.2	.
2003	26.1	5.7	6.3	19.8	.
2004	-4.9	20.4	-9.7	4.8	.
2005	-6.2	3.7	8.5	-14.7	.
2006	-3.6	4.0	8.2	-11.8	.
2007	9.3	1.6	10.8	-1.5	.
2008	8.7	2.5	9.8	-1.1	.
2009	42.6	-23.5	38.1	4.5	.
2010	36.4	-8.3	21.5	14.9	.
2011	39.1	-25.1	39.8	-0.7	.
2012	-30.4	-2.0	14.7	-45.1	.
2013	-21.3	47.1	-38.7	17.4	.

2014	32.0	-6.3	19.4	12.6	.
2015	-14.9	4.4	7.7	-22.6	.
2016	-1.8	10.1	1.5	-3.3	.
2017	30.4	-12.5	26.1	4.3	.
.	.	43.3	-34.6	.	20.4

The model below is estimated by ordinary least squares using the data in the table above.

$$\underset{(4.14)\,(0.24)}{price = 12.5 - 1.09\ slaughter}$$

$$s = 17.04, R - sq = 0.5868, DW = 2.19$$

The figures in parentheses below the coefficients are their respective standard errors. The other summary statistics are: *s* the residual standard error, *R-sq* the squared correlation coefficient, and *DW* the Durbin-Watson statistic for first-order serial correlation.

Both of the coefficients are statistically significant at the usual significance levels. The *R-sq* value closely replicates the Mecardo report value 0.5839 for their model, while the *DW* statistic indicates no significant serial correlation at first order. The value of *s* is responsible for the large forecast standard error reported in the table and discussed in the text.

Appendix 3: Stata code

```
use "Mecardo data.dta"
regress price slaughter
set obs 18
replace slaughter=43.3 in 18
predict model, xb
predict resid, residuals
predict sef in 18, stdf
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