The Impact of Market Structure on Pass-through of International Beef Prices to Local Cattle Prices

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Abstract. This thesis examines the effect of horizontal market structure among beef cattle producers on pass-through of international beef prices to local saleyard cattle prices. The measure of market concentration used is the Herfindahl-Hirschman Index ("HHI"). HHIs are constructed using newly-available disaggregated cattle herd size data for 9 regions across the state of New South Wales. A time-invariant HHI for each region is interacted with international beef price and fixed effects ordinary least squares techniques are applied. The analysis yields that market concentration among beef producers is significantly negatively related to pass-through of anticipated international beef prices. No significant effect of horizontal market structure on pass-through of contemporaneous or lagged international beef prices is identified. It is argued that these findings are likely due to the interaction between horizontal and vertical market structure in the NSW beeef supply chain. This thesis also explores whether the estimated effect of market structure on pass-through is affected by the inclusion of exchange rate pass-through effects in the model. It is found that the inclusion of an exchange rate term does not greatly influence the estimated effect of market structure on international beef price pass-through, although the results indicate that the effect of market structure on pass-through of exchange rates is larger in magnitude.

Acknowledgements

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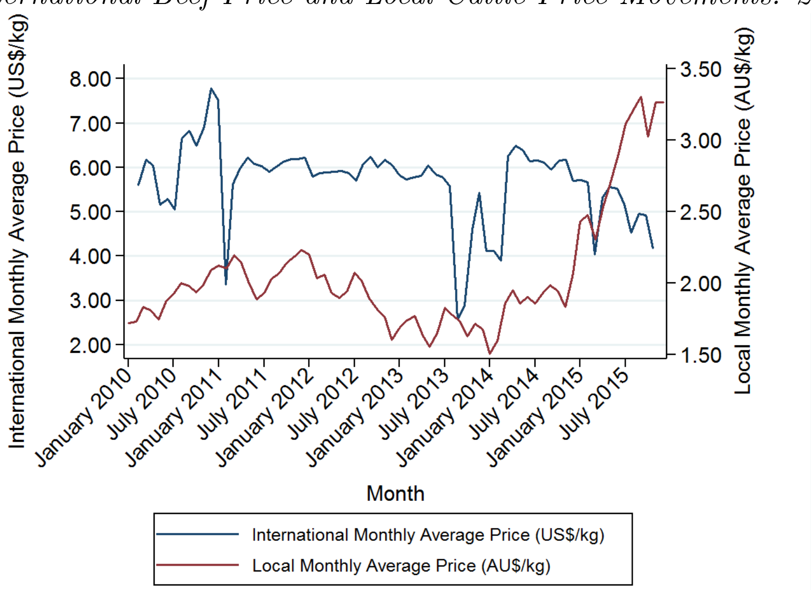
CHAPTER 1

Introduction

1.1. Background

It is a common assertion of beef industry analysts that over the past two decades the best indicator of domestic Australian beef cattle prices has been international beef prices. In fact, agricultural market analysts Mecardo declare that more than 85% of yearly variation in Australian cattle prices can be explained by changes in overseas prices (Semmelroth (2015)). Despite claims of this kind, very little formal analysis has been conducted to ascertain whether or not pass-through of international beef prices is as high or as consistent as is commonly believed.

FIGURE 1. *International Beef Price and Local Cattle Price Movements: 2010-2015*



Note: The international beef price series used here is calculated according to the processes outlined in section 3.3. The local cattle price time series uses the average monthly yearling steer price at the Dubbo saleyards in the NSW Central West region.
Source: UN Comtrade (2016); MLA NLRS (2016).

Figure 1 graphs international beef prices alongside local cattle prices for the 2010-2015 period. It indicates that, although international beef prices and domestic cattle prices generally follow similar trends, there are variations in local cattle price that are not explained by international beef prices. The most striking of these is a persistent increase in local cattle prices from late 2014-15 despite a fall in international beef prices over the same period. This divergence can be largely explained by local factors such as widespread rainfall in Eastern Australia during that time. Whilst local factors such as rainfall may be difficult to predict, one local factor that might be assumed to have a measurable and predictable effect on pass-through of international beef prices is market concentration. The existing literature on pass-through suggests that, where horizontal market concentration is high, pass-through of exchange rates, costs and taxes will be low (see for example Burstein and Gopinath (2015); Hong and Li (2013)). One might also expect this inverse relationship to apply to pass-through of international beef prices. Despite this logical nexus, prior to this paper no formal research has looked at the effect of market concentration on the relationship between international and local prices.

Indeed, not only has there been no research into the effect of market structure on price pass-through, but there exists little literature concerning the broader relationship between market structure and prices in the Australian beef industry. As a consequence, Ferry and Parton (2009) consider understanding of the structure of the Australian beef industry to be at an "embryonic" stage. Despite this general lack of empirical analysis in the area, policymakers in Australia have long been concerned by the possibility that market concentration in the beef industry leads to inefficiencies such as depressed output prices for producers and inflated beef prices for consumers. In 1994 the forerunner of the Australian Productivity Commission, the Industry Commission, identified that Australia's ability to produce meat at internationally competitive prices was not due to efficient processing of the meat, but rather the ability of processors to use market power to drive down the price at which they purchased livestock (Industry Commission (1994)).

Concerns as to the impact of vertical and horizontal market structure on beef and cattle prices have persisted in the intervening decades, culminating in two current Australian government inquiries. In 2015 the Australian Senate Rural and Regional Affairs and Transport References Committee announced an inquiry into the effects of increased market concentration in the red meat processing industry (Senate Inquiry Terms of Reference (2015)). That inquiry has not yet been completed, although the Senate Inquiry Interim Report (2016) notes that there is widespread concern about the impact of increasing market concentration and vertical integration on "farmgate" prices (prices received by cattle producers). Additionally, the Australian Competition and Consumer

Commission ("ACCC") is currently undertaking a market study of the cattle and beef sector in order to better understand market structure at all stages of the beef supply chain (ACCC (2016)). The broader purpose of both inquiries is to identify whether or not the market structure of the beef industry is a source of price distortion in the Australian economy and to provide policy options for correcting any such inefficiency. Hence, understanding pass-through of international beef prices is relevant not only for the purpose of enabling more accurate prediction of local cattle prices, but is also relevant to policymakers seeking to reduce inefficiencies introduced by the exercise of market power.

1.2. Aim

In light of the ongoing policy interest in the effect of beef industry market structure on prices and the relative dearth of empirical analyses on the subject, this thesis aims to fill a gap in the existing literature. It is hoped that this thesis will help to develop understanding of the interplay between market structure and prices in the Australian beef industry from the embryonic stage to infancy.

Specifically, the aim of this thesis is to determine whether market concentration among beef cattle producers has an impact on pass-through of international beef prices.

In order to investigate this query, this paper applies an ordinary least squares model with fixed effects to a panel of 9 regions within New South Wales ("NSW") for the 2010-2015 period. By looking at the interaction of international beef prices and market concentration, it is possible to identify the impact of changes in market concentration on pass-through of international beef prices to local cattle prices across these 9 regions.

1.3. Summary of Findings

In general, the data indicates that the level of market concentration in beef production is low, with all regions exhibiting high levels of horizontal competition. Consequently, pass-through literature (such as Atkeson and Burstein (2008); Hong and Li (2013); Burstein and Gopinath (2015)) may lead one to hypothesise that, absent any countervailing effect of vertical market structure, pass-through will be generally high, with regions exhibiting higher levels of market concentration likely to exhibit lower levels of pass-through.

In fact, no significant effect of market concentration on pass-through of current or past international beef price is identified. This result is consistent with the idea that high levels of market power further along the supply chain diminish pass-through to the extent that horizontal market power among cattle producers can have only a minimal influence.

In contrast, the main finding of this paper is a significant negative relationship between market concentration and pass-through of anticipated changes in international beef prices. It is estimated that, should 10 beef producers each with 1% of total market share merge into a single production entity with 10% of market share, this would reduce pass-through of anticipated future international beef prices by 0.028%. It is also found that market concentration reduces pass-through of the exchange rate, with the same change in market concentration predicted to reduce pass-through of anticipated changes in the exchange rate by 0.384%. Both findings are consistent with general models of pass-through which predict that firms with horizontal market power will absorb part or all of an exogenous shock by reducing their margin and will not pass as much of the change on to purchasers as would be expected under perfect competition.

There does not seem to be any existing theoretical explanation as to why market structure's effect on pass-through is limited to pass-through of anticipated changes. It may be that the effect of international beef prices on domestic cattle prices is anticipatory and dissipates quickly. For instance, it might be the case that the vertical structure of the industry is such that it dampens pass-through of current and past prices but is responsive to expected price shocks. In that case, pass-through of current and lagged prices would be small and the effect of changes in market concentration among producers would be minimal. Meanwhile, the higher rate of pass-through of anticipated changes would permit greater variation in pass-through according to producer concentration.

The results obtained in this analysis are robust to different measures of market concentration and exchange rates and are not driven by extreme variation in local cattle prices. However, the findings may be influenced by the small amount of observed variation in market concentration in the sample and are not robust to different measures of international beef price.

1.4. Structure

This thesis is structured as follows. Chapter 2 expands upon the above discussion of how this paper relates to the existing literature. The existing literature is also used to draw hypotheses which help to provide further intuition for the results of the analysis. The following Chapters then describe the methodologies used and results obtained. In Chapter 3 the data is described along with the processes used to compile the unique dataset that forms the basis for this analysis. Chapter

4 sets out the empirical techniques and models applied in order to address the research aims of the paper. In Chapter 5 the results of the analysis are discussed in further detail. Chapter 6 then presents several robustness checks. Finally, Chapter 7 identifies the main conclusions and policy implications to be drawn from the results presented in this thesis.

CHAPTER 2

Related Literature

There is little literature that specifically examines the effect of market structure on pass-through, with most papers addressing the issue only tangentially. There exists literature that deals with the way in which varying market structures affect pass-through of exchange rates, input costs and taxes; however, no existing literature looks at the impact of market structure on pass-through of international commodity prices into domestic market prices. Despite this lack of directly applicable theory, this paper's analysis is not conducted in a theoretical vacuum. To inform the empirical analysis, this Chapter draws on three separate strands of literature: it first looks to empirical studies identifying the market structure of the Australian beef industry and then links the structural features identified to pass-through literature and industrial organisation literature.

2.1. Market Structure in the Australian Beef Industry

The Australian beef industry is quite geographically segmented, with most of Australia's beef production occurring in Queensland and NSW (ANZ (2015)). According to Thompson and Martin (2012), beef cattle production in the Northern Territory and Western Australia focuses primarily on live cattle exports. In Queensland the majority of output is allocated to beef export markets. In contrast, in southern states such as NSW and Victoria, production is split more evenly between beef exports and the domestic beef market. Further, Thompson and Martin indicate that the geography and climate of northern Australia (Western Australia, Northern Territory and Queensland) requires farms to be larger both in herd size and property size than their southern counterparts in order to be economically viable. They calculate that in northern Australia 86% of the beef cattle herd is on properties with more than 800 cattle, while only 35% of the southern beef cattle herd can be found on properties of that size.

Little independent analysis has been conducted in relation to the degree of competition in the beef cattle industry, with most estimates having been constructed by market consultants for the purpose of compiling submissions for government inquiries (see for example JBS (2015)). Of the independent analysis that has been conducted, the findings tend to be contradictory and only one directly relevant paper has been published since the year 2000. In general, research has tended to begin with the working hypothesis that beef production in Australia is competitive but that there might be oligopsonistic factors affecting other aspects of the supply chain, in particular supermarkets and beef processing firms. The interim report of the Senate Rural and Regional Affairs and Transport References Committee inquiry into red meat processing notes that:

> "[6.8]...market power can be revealed in a number of ways within these complex supply chains. Submitters detailed examples of non-competitive terms and prices, asymmetric information, and price discrimination." (Senate Inquiry Interim Report (2016))

In this regard, Griffith et al (1991) find that short run price levelling is pervasive in Australian retail meat markets, a characteristic inconsistent with competitive behaviour. Further, Chang and Griffith (1997) find that retail prices can be considered as weakly exogenous to the prices paid to producers, which could indicate a noncompetitive market structure. These findings are consistent with ongoing suspicions as to the existence of an oligopsony in the processing and retail stages of the beef supply chain. In contrast, according to Hyde and Perloff (1997) the domestic retail market for meat has not changed significantly in structure over time and is competitive for beef, lamb and pork.

Despite the geographical segmentation of the Australian beef industry being commonly accepted as fact, even less analysis has been conducted which differentiates either between regions or according to whether a market is dominated by domestic or export sales. One paper that does account for market segregation is Zhao et al (1998). In that paper the authors treat domestic and export markets as being separate, finding that pricing in the domestic market is competitive, while the export market exhibits noncompetitive pricing behaviour. They identify several key features of the export industry, including barriers to entry in the form of exporter licensing arrangements and export quantity restrictions, that may contribute to market power. Additionally, the authors suggest that the high degree of vertical integration in the export industry supply chain likely explains much of the noncompetitive pricing behaviour identified by their model.

The only significant discussion of market structure in the Australian beef industry conducted this century is contained in Ferry and Parton (2009), in which the beef supply chain in Australia is compared with those of the United States and United Kingdom. In that paper the authors note that, due to the "embryonic" stage of analysis in the area, a broad approach is necessary to obtain an overview of market structure. This broad perspective includes qualitatively identifying the level of market concentration in the four main stages of the beef supply chain (production, feedlotting, processing and retail). They find that market concentration of producers in Australia is "medium" (higher than the "low" identified for both the United States and United Kingdom). The feedlotting industry is also thought to be of medium concentration, while the processing industry is highly concentrated. Lastly, beef retailing is considered to be of medium to high concentration, although it is noted by the authors that the significant export market for Australian beef reduces the market power of domestic supermarkets.

According to one industry estimate, approximately 57% of beef processing is carried out by large processors (processors of more than 100,000 cattle per year) (JBS (2015)). This is consistent with the suspicion that there is some oligopsonistic behaviour occurring at the processing stage. In this regard, the interim report of the Senate Committee inquiry identifies that:

> "1.25 One of the primary characteristics of the cattle industry is that cattle production is highly diverse and fragmented, comprising thousands of family farms across the country. In direct contrast, the red meat processing sector is highly consolidated and corporatised." (Senate Inquiry Interim Report (2016))

Additionally, one of the findings of the interim report is that meat processors are increasingly focusing on vertical integration. For example, JBS, the largest meat processing company in Australia which accounts for nearly 17% of all beef processing (JBS (2015)), owns 12 abbattoirs and is also increasingly conducting cattle fattening operations through its 5 feedlots (Senate Inquiry Interim Report (2016)). According to one submission, processors now own more than a fifth of total feedlotting capacity in Australia.

From this overview, it seems apparent that horizontal market concentration is low among beef cattle producers in Australia; however, as one looks further along the supply chain, market power becomes increasingly prevalent. It also seems apparent that there is significant geographical variation in both horizontal and vertical market structure. For instance, given the relatively few farms in southern Australia with large herd sizes, it is likely that horizontal market concentration in NSW is less than that of Queensland. Further, the NSW supply chain is probably less concentrated than in northern Australia, as NSW producers interact in the domestic market (which according to Zhao et al (1998) exhibits competitive pricing) in addition to the beef export market. One can also conjecture that this factor might lead to variation within NSW, as some regions may interact in the export market more than others, leading to non-competitive price effects.

2.2. Market Structure and its Relationship to Pass-through

2.2.1. Pass-through of Exchange Rates. Discussion of pass-through most commonly relates to discussion of the extent to which exchange rate variation feeds into import prices and domestic inflation (see McCarthy (2000); Chung et al (2011)). Due to its focus on general price level effects, literature on pass-through of the exchange rate generally does not engage with the effect of market structure beyond noting that price markups tend to be larger in less competitive industries (see, for example, Burstein and Gopinath (2015)). Consequently, pass-through rates are lower in more concentrated markets as firms are already extracting large amounts of consumer surplus and will not benefit significantly from changing their output prices in response to changes in the exchange rate.

2.2.2. Pass-through of Costs. Farrell and Shapiro (2010) argue that tests which use the rate at which cost increases are passed on to consumers as an indicator of market structure incorrectly assume that there is a rigid relationship between cost pass-through rates and market concentration. However, they agree with the exchange rate literature that, ceteris paribus, a firm with market power will have a lower pass-through rate than a competitive firm.

More recently Hong and Li (2013) develop an extensive model of cost pass-through in the United States retail industry which allows pass-through to vary according to horizontal and vertical market structure. They find that, controlling for other factors, the existence of vertical market power (such as oligopolies and/or oligopsonies) reduces pass-through as firms with market power are less sensitive to exogenous shocks. Similarly, greater horizontal market share is found to reduce pass-through. Interestingly, they find that vertical integration increases pass-through of costs as it reduces the number of separate profit margins applied to a single good throughout the production and retail process. Thus, in a supply chain containing oligopsonistic stages, the more vertical integration, the lower the price markup and the higher the pass-through.

2.2.3. Pass-through of taxes. Tax incidence is somewhat analogous to pass-through of costs. The theory of tax incidence under perfect competition is well known to all those who have studied introductory microeconomics: a tax is borne by the side of the market that is more inelastic.[1] Both Delipalla and O'Donnell (2001) and Reny et al (2012) develop extensions to this basic theory that deal with tax pass-through under oligopoly with potentially asymmetric firms. Although both of

[1] A similar formulation of this tax burden rule can be found in any introductory microeconomics textbook. See for example Morgan et al (2009).

these papers formulate a model of tax incidence under oligopoly, neither provides a complete analysis as to how this differs from pass-through under other market structures.

Perhaps the most detailed theoretical analysis of the relationship between pass-through and market structure is to be found in Weyl and Fabinger (2013). In that paper the authors examine the principles of tax incidence under a base model of perfect competition before extending the model to deal with monopolies and symmetric imperfect competition. In the perfect competition case, the formula derived for pass-through is similar to the traditional formula for tax incidence in that it is dependent only on the relative elasticities of demand and supply: $\rho = \frac{1}{1+\epsilon_D/\epsilon_S}$. Weyl and Fabinger's formula for pass-through under monopoly differs from the perfect competition scenario slightly, primarily through the inclusion of an elasticity of marginal consumer surplus (ϵ_{ms}) term: $\rho = \frac{1}{1+\frac{\epsilon_D - 1}{\epsilon_S}+\frac{1}{\epsilon_{ms}}}$. Finally, pass-through under symmetric imperfect competition is expressed as a linear combination of the two, with the weighting on monopoly being θ and the weighting on perfect competition being $(1-\theta)$: $\rho = \frac{1}{1+\frac{\theta}{\epsilon_\theta}+\frac{\epsilon_D - \theta}{\epsilon_S}+\frac{\theta}{\epsilon_{ms}}}$. At the most superficial level, the fact that each formula is different indicates that pass-through will differ according to the level of competition in the market. Further, ceteris paribus, if $\frac{1}{\epsilon_s} < \frac{1}{\epsilon_{ms}}$, then a monopolist will raise prices by less than a perfectly competitive firm in response to a tax increase. If it is assumed that a monopolist extracts as much consumer surplus as possible by operating on the inelastic portion of the demand curve (a simple assumption often used in introductory microeconomics), it seems likely that ϵ_{ms} will be low and therefore pass-through will be lower under monopoly than under perfect competition. As Weyl and Fabinger (2013) formulate pass-through under symmetric imperfect competition as a linear combination of the two, this implies that pass-through is highest for a monopoly and decreases as market concentration falls.

From this exposition there seems to be a consistent conclusion to be drawn in relation to pass-through of costs, taxes and exchange rates: all other things (most notably the elasticities of supply and demand) being equal, theorists would expect less competitive markets to exhibit lower pass-through rates. It is important to note that this theory is almost exclusive to pass-through of costs. The literature on exchange rate pass-through largely discusses the effect of an exchange rate change on the price of imports, and how this cost change is passed through into prices. In the case of tax pass-through it is assumed that a tax is levied on producers, essentially acting as an exogenous increase in costs. However, this thesis does not examine the pass-through of costs. The mechanism through which pass-through of international beef prices into the local cattle market occurs is export prices, not import prices, input costs or taxes. If the pass-through literature applies, one would expect that regions with lower producer concentration will exhibit higher pass-through of international beef prices. It may be hypothesised, in line with the the available literature, that the highly horizontally competitive nature of beef production described in section 2.1 will mean that pass-through of international beef prices will be generally high and regions with less competitive markets will be less responsive to changes in international beef prices. This is because firms with market power maximise their markup and are thought to be less sensitive to exogenous factors. However, it is uncertain whether this understanding of price transmission, developed in relation to supply-side shocks, will extend to transmission of international beef prices.

2.3. Vertical Market Structure and its Effect on Prices

As emphasised by the analysis of Hong and Li (2013), both horizontal and vertical market structure play a role in determining pass-through. In order to understand the way in which these factors interact more fully, it is useful to examine the price effects of various supply chain structures. The discussion in section 2.1 suggests that industrial organisation literature dealing with oligopsony may shed some light on the effect of the concentrated nature of the beef processing and retail industries on local cattle price sensitivity and pass-through. Similar to pricing of inputs under monopsony, it is widely accepted that in a transaction between a competitive producer and an oligopsonistic firm, the price received by the producer will exhibit a markdown as a result of the oligopsonist's market power (Andersen et al (2008)).

Issues of market power in agricultural supply chains have been studied much more widely in North America and Europe than in Australia.[2] Rogers and Sexton (1994) posit a theoretical model of the European market for raw agricultural products, finding that such markets are likely to be structural oligopsonies. They find that buyer concentration, transport costs and noncompetitive buyer conduct in such industries may combine to create large farm to retail price spreads.

Of particular relevance to this analysis are several recent papers dealing with the effect of monopsony power in the United States and Canadian beef processing industries. Andersen et al (2008) note that the spike in research in this area over the last three decades has been driven by concerns that the increasing prominence of large meat processing and retailing firms in North

[2]Indeed, there seems to be no empirical research into the beef supply chain structure in Australia beyond that presented in section 2.1.

America has the potential to simultaneously drive cattle prices down for producers and beef prices up for consumers. These concerns echo those of Australian policymakers.

Schroeter (1988) conducts a large empirical study using annual data for a 33-year period from 1951 to 1983 in the Unites States. For 28 of the 33 years studied, Schroeter finds statistically significant evidence of non-competitive conduct by beef packing companies. Oligopsonistic behaviour by beef packers is estimated to account for approximately 55% of the farm to retail price spread over the period. Despite this, the overall price distortions were relatively small in magnitude, with the oligopsonistic markdown estimated to amount to only 1% of the cattle price received by farmers. Interestingly, evidence of oligopsony price distortion decreased during the final years of the sample period, despite market concentration of meat packers increasing over time.

Azzam and Pagoulatos (1990) also attempt to identify the impact of oligopsonistic conduct in the United States' meat packing industry. Their study uses data for the period 1959 to 1982, and finds that market power in the meat packing industry led to price distortions in both the cattle market and the retail beef market over the period. More specifically, the authors find that the oligopsony power of meat packing firms was significantly higher than their oligopoly power. That is, the market power of meat processors is found to lead to a substantial price markdown in the livestock market, but only a small distortion in the retail beef market.

Similar studies have also been conducted on a region-by-region basis. For example, Azzam and Shroeter (1991) look at the degree of concentration in the beef packing industry at a local level, estimating oligopsony price markdowns in 13 regional cattle markets within the United States in 1986. This regional analysis yields slightly smaller price distortions than those identified by earlier studies. On average, livestock price markdowns are estimated to be less than 1% of the price received by producers.

Schroeter et al (2000) create a model allowing analysis of the role of meat processors as both oligopsonies (purchasing from producers in the cattle market) and oligopolies (selling to retailers in the beef market). Additionally, they attempt to model the simultaneous exercise of market power by processors and retailers in the United States beef supply chain. They find that retailers exercise oligopolistic market power in sales to consumers, but that the interaction between processors and retailers is largely a bargaining process which leads to relatively competitive outcomes. Additionally, in contrast to previous studies, meat packers are found to act largely as price takers with little evidence of distortionary behaviour.

Bucking the recent trend towards identification of little or no oligopsonistic price distortion by meat processors in livestock markets, Ji et al (2016) find that there exists oligopsony market power in the United States' cattle procurement market. Interestingly, they also find that oligopsonistic price setting behaviour is sensitive to cattle herd numbers; that is, the size of the markdown applied is larger in seasons of excess cattle supply and smaller during periods of supply shortage.

Using Canadian data, Rude et al (2010) conclude that there is little evidence of monopsony power in that country's beef packing industry. They find that Canadian meat packers do not pay less for cattle than is justified by their procurement costs. The authors argue that this finding contradicts the belief that a highly concentrated industry will necessarily exercise market power through price markups or markdowns. They posit that such market power can only be exercised where Canadian producers and feedlotters do not have the option of exporting cattle to the United States. This conclusion contrasts with the finding of Zhao et al (1998) that the Australian export market is less competitive than the domestic market, but is consistent with the analysis of Ferry and Parton (2009), which indicates that export opportunities reduce the ability of Australian supermarkets to use their market power to influence cattle prices. If the reasoning of Rude et al (2010) is accepted, it may be supposed that cattle prices in Queensland, where beef production is almost entirely export-oriented, will exhibit less oligopsonistic markdown than in NSW. Unfortunately, as detailed in section 3.1, comprehensive Queensland data is unavailable, preventing this thesis from further investigating that avenue of comparative analysis.

It is difficult to reconcile the findings of the North American literature with the Australian research summarised in section 2.1. The Australian studies described are broadly consistent with their contemporaneous North American counterparts (Schroeter (1988); Azzam and Pagoulatos (1990); Azzam and Shroeter (1991)); however, the more recent North American literature tends to diverge in finding little or no price distortion caused by the existence of oligopsonies in beef processing and retail. Given that the few Australian studies that have taken place this century have tended to focus on identifying the structure of the market and do not attempt to quantify any accompanying distortionary price effects, it is difficult to predict with certainty whether or not the presence of processing oligopsonies in Australian markets has the impact of lowering livestock prices received by producers. If it is the case that there exists an oligopsonistic markdown in the Australian industry, one might expect that pass-through will be lower in regions where processors have extensive market power, as they are already maximising their profit margin and will be less sensitive to international beef price changes. This effect would, to some extent, offset the effect of high levels of competition among producers (which, according to the literature, would tend to increase pass-through) and the rate of pass-through would then be determined by the relative dominance of the two factors. If the more recent North American literature applies and Australian cattle prices do not exhibit an oligopsonistic markdown, it seems likely that local cattle prices will be sensitive to international beef price changes and horizontal market structure among producers will play a larger role in determining pass-through.

CHAPTER 3

Data

The dataset used is unique and was compiled for the purpose of conducting analysis for this thesis. It comprises monthly data covering the period January 2010 to December 2015 from four distinct sources: NSW Local Land Services, Meat and Livestock Australia, United Nations Comtrade and the Reserve Bank of Australia. This Chapter describes the nature of the data and the processes used to transform it in order to interrogate the research question.

3.1. Market Structure Data

Market structure data for the beef cattle industry are generally difficult to find.[3] As a measure of market share, beef cattle herd numbers for NSW were obtained. Notably, these data have not previously been made available for independent economic research. Unfortunately, comprehensive data of this nature are not routinely collected for other Australian states. NSW Local Land Services ("LLS") collects annual beef herd numbers for each land holding in NSW. This information is reported to the LLS by producers as part of the Annual Land and Stock Return process. It is used by the LLS to calculate the rates paid by landholders and for that reason there is an incentive for producers to under-report herd numbers. However, given the potential for reported herd size to be checked against the National Livestock Identification System ("NLIS") database[4] and the way in which services are distributed according to holding and herd size, any bias due to under-reporting is likely small. As suggested by the name of the LLS survey, these data are annual in nature unlike the monthly data described in the following sections. They indicate that in NSW in 2010, 29% of beef cattle could be found on properties with over 800 cattle, which is a slightly lower proportion than that estimated across southern states by Thompson and Martin (2012). In addition to herd size, the data identify

[3]Data as to the number of cattle sold by each vendor at each beef cattle sale in NSW would have been ideal for this research; however, this information is not retained by Meat and Livestock Australia.

[4]The NLIS database also contains a record of all beef cattle on each property as it requires an electronic identification device to be attached to each animal. However, it exhibits the opposite problem to that observed in the LLS data; cattle numbers are likely overestimated on the NLIS database. This is because producers must activate new devices in advance of purchasing/breeding cattle and many devices are lost without being deactivated or removed from the database.

the region to which each land holding belonged. There are 11 LLS regions in NSW.[5] This allows the below analysis to be conducted at the regional level rather than using state-wide estimates.

An HHI was constructed for each region. The HHI accounts for the number of producers in a market as well as market concentration by focusing on the relative size of all entities in the market (Hirschman (1964); Rhoades (1993)). It is constructed by summing the squared market share of all producers. For this analysis, the herd size data were used to determine the herd share of each landholding as a proportion of total regional herd size. An annual HHI for each region was then calculated:

$$s_{kt} = \frac{x_{kt}}{\sum_{k}^{N} x_{kt}} \cdot 100 \tag{3.1.1}$$

$$HHI_{ct} = \sum_{k} s_{kt}^2 \tag{3.1.2}$$

Where:

- N is the total number of firms in region c;
- x_{kt} is the number of beef cattle on landholding k in year t; and
- HHI_{ct} is the Herfindahl Hirschman Index for region c in year t.

HHIs are typically reported as a point on the interval $(0, 1]$ where an HHI of $0 + \varepsilon$ represents a perfectly competitive market and 1 represents a monopoly. In this analysis the market share is multiplied by 100 in equation 3.1.1 and the resulting market shares, expressed as percentages, are used in equation 3.1.2. This results in an HHI on the interval $(0, 10000]$ where perfect competition is as before and $10,000$ represents a monopoly. This transformation was done to bring this analysis in line with the methods used by the ACCC.

3.2. Local Cattle Price Data

Local cattle price information was obtained from Meat and Livestock Australia's National Livestock Reporting Service ("NLRS").[6] Monthly average prices (in AU$/kg) for yearling steers were

[5] Central Tablelands, Central West, Greater Sydney, Hunter, Murray, North Coast, North West, Northern Tablelands, Riverina, South East and Western.

[6] Selected data can be obtained from http://www.mla.com.au/prices-markets/Market-reports-prices/. The NLRS provided more comprehensive price data for this research.

obtained for each saleyard in NSW. The largest saleyard in each LLS region was then selected and observations from other saleyards dropped.[7]

3.3. International Beef Price Data

These data originated from the United Nations Comtrade database.[8] Monthly export[9] volumes (in kilograms) and value (in US$) of chilled and fresh bovine meat[10] for all nations were extracted from the database. The reasons chilled and fresh meat data were chosen instead of live export data were twofold. First, the live cattle and meat market in Australia are quite geographically distinct and NSW is not a significant contributor to live exports (Thompson and Martin (2012)). Secondly, the local cattle price data is saleyard data and saleyards are not commonly used as intermediaries in the live export trade.

The value and volume data were then used to construct a monthly international beef price variable:

$$P_t^I = \frac{\sum_j Value_{jt}}{\sum_j Volume_{jt}} \tag{3.3.1}$$

Where the j subscript is a nation index and P_t^I is the international price of bovine meat in US$/kg in month t.

3.4. Exchange Rate Data

The Trade-Weighted Index ("TWI") for the final trading day of each month was obtained from the Reserve Bank of Australia's historical database.[11] This measure is indexed to a base period of May 1970 ($TWI_{May\ 1970} = 100$).

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[7] Small saleyard data were not used as their sales tend to be less regular and therefore contained many missing observations. The largest saleyard was selected by identifying which saleyards in each LLS region had the fewest missing observations, and, if more than one, which one most commonly had the largest herding of yearling steers.

[8] http://comtrade.un.org/data/.

[9] Imports were ignored to prevent duplication.

[10] Bovine meat is the most appropriate classification available in the UN Comtrade data. Beef accounts for a large proportion of the volume of bovine meat traded internationally; however, this measure does also include meat of other bovine animals such as buffalo and bison.

[11] http://www.rba.gov.au/statistics/historical-data.html.

3.5. Combined Dataset

The individual datasets described above were merged, matching each observation according to month, to form the combined dataset used in the the following analysis. Despite market herd size data being available for 11 regions in NSW, two of these (Greater Sydney and Western) do not have saleyards that consistently report price outcomes, leaving 9 regions to which local cattle price data could be matched. The result is an unbalanced panel dataset containing 9 regions and 581 observations for the period January 2010 to December 2015. The price and HHI characteristics of each region are displayed in Table 1.

TABLE 1. *Descriptive Statistics: Region Characteristics*

Variable	Central Tablelands			Central West			Hunter		
	Mean	Min.	Max	Mean	Min.	Max	Mean	Min.	Max
P_{ct}^{local}	2.10	1.57	3.34	2.06	1.51	3.30	1.98	1.26	3.18
HHI_{ct}	16.72	13.46	20.99	19.90	18.17	22.18	19.79	17.30	21.63
$ln(P_{ct}^{local})$	0.73	0.45	1.20	0.70	0.41	1.20	0.67	0.23	1.16
Observations	72			72			72		
	Murray			**North Coast**			**North West**		
	Mean	Min.	Max	Mean	Min.	Max	Mean	Min.	Max
P_{ct}^{local}	1.96	1.38	3.29	1.84	1.21	3.13	2.07	1.52	3.26
HHI_{ct}	55.71	29.06	120.07	11.14	5.78	35.25	31.44	23.01	38.42
$ln(P_{ct}^{local})$	0.66	0.32	1.19	0.59	0.19	1.14	0.71	0.42	1.18
Observations	71			72			72		
	Northern Tablelands			**Riverina**			**South East**		
	Mean	Min.	Max	Mean	Min.	Max	Mean	Min.	Max
P_{ct}^{local}	2.00	1.36	3.28	2.05	1.29	3.33	3.07	2.89	3.18
HHI_{ct}	38.82	30.31	46.45	162.78	95.55	279.56	16.06	16.06	16.06
$ln(P_{ct}^{local})$	0.67	0.31	1.19	0.70	0.25	1.20	1.12	1.06	1.16
Observations	72			72			6		

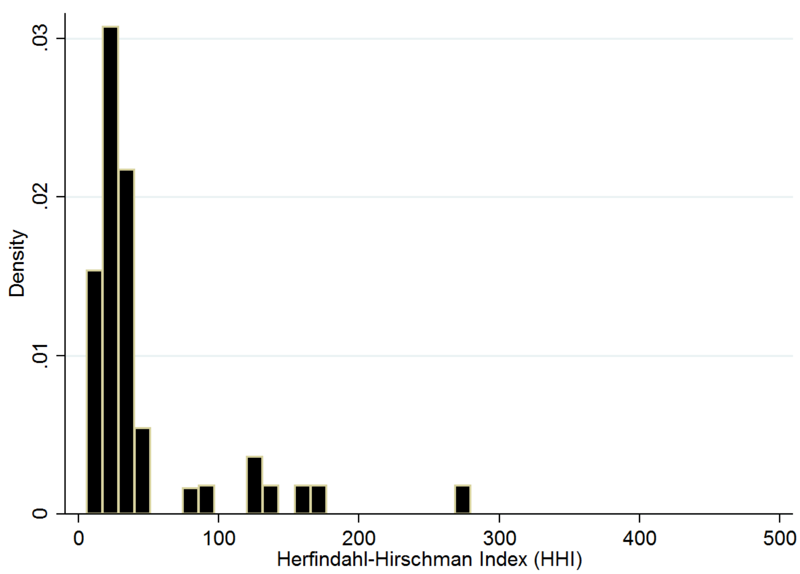
Note: c subscripts refer to region and t subscripts to month. The HHI statistics presented here relate to the annual HHI calculated for each region. Later in the analysis the means from this table are used as a time-invariant measure of competition.

Most of the panels contain 72 observations covering all months of the 6 year period; however, April 2010 is missing from the Murray region data as no sales were held at that region's selected saleyard during that month. Additionally, the South East region data contains only 6 observations as prior to July 2015 no saleyards in that region reported price information.

As can be seen from Table 1, each of the regions exhibit HHI values that are very close to the lower bound of the $(0, 10000]$ interval, indicating beef cattle production is highly competitive.

The ACCC's Merger Guidelines indicate that horizontal competition concerns will be unlikely to arise where the relevant HHI value is less than 2000 (ACCC (2008)). The US Department of Justice Antitrust Division uses the same HHI calculation method and considers an industry with an HHI of less than 1000 to be "unconcentrated" or "mildly concentrated" (US Department of Justice (2015)). Figure 2 shows the distribution of HHI values observed in the data. The HHIs are largely clustered between 0 and 50, and the highest HHI observed is 279.56, at the lower end of the "unconcentrated" range.

FIGURE 2. *Histogram: HHI Values for all Regions*



In the below analysis the intra-region average is used rather than month-to-month variation in the HHI in order to alleviate concerns that the local cattle price is endogenous to monthly changes in regional market concentration. Descriptive statistics on key variables from the combined dataset used are provided in Table 2.

TABLE 2. *Descriptive Statistics: Panel*

Variable	Mean	Std. Dev.	Min.	Max	Obs.
P_{ct}^{local}	2.0188	0.427641	1.2115	3.335	581
P_t^I	5.657801	0.9091031	2.572618	7.790651	581
HHI_c^{Ave}	44.24044	46.61354	11.14092	162.7807	581
TWI_t	71.5389	5.406653	59.9	79.2	581
$ln(P_{ct}^{local})$	1.717261	0.1882989	0.9449242	2.052924	581
$ln(P_t^I)$	0.68274	0.1937396	0.1918593	1.204473	581
$ln(TWI_t)$	4.267303	0.0773263	4.092677	4.371976	581
$ln(P_t^I) \cdot HHI_c^{Ave}$	76.01748	81.03196	10.52732	334.1764	581
$ln(TWI_t) \cdot HHI_c^{Ave}$	188.8362	199.0642	45.59617	711.6732	581

Note: c subscripts refer to region and t subscripts to month.

CHAPTER 4

Empirical Methods

This thesis uses ordinary least squares ("OLS") regressions to examine the impact of market structure in the beef cattle market on pass through of international beef prices. As the local cattle price and competition data are region-specific, it is possible to apply rigorous panel data estimation techniques that account for both time and region fixed effects. Beef cattle prices in NSW are affected by many additional factors, both observed and unobserved, such as rainfall, fodder conditions and input prices. Controlling for both time and region fixed effects enables examination of the impact of international beef prices and market structure whilst minimising the risk of omitted variable bias.

A log-log model is used to examine the effect of international beef price and its interaction with HHI on local cattle prices. This ensures that differences in the measurement units of the price variables do not influence the results of the model. In order to determine whether this specification is appropriate, stationarity tests were conducted on the international beef price and local cattle price time series. Using both the Augmented Dickey-Fuller test (H_0 : series is not stationary) and the Kwiatkowski-Phillips-Schmidt-Shin test (H_0 : series is stationary) it was concluded that the international beef price time series is stationary. This finding was supported by an AR(1) coefficient of 0.54. For the local cattle price time series the Im-Pesaran-Shin test (H_0 : all series are not stationary) was used and it was concluded that at least one of the local cattle price series is stationary.[12] Again, the AR(1) coefficient of 0.62 supported the finding of stationarity. Given these conclusions, it is likely that the standard errors and t-statistics obtained from the OLS fixed effects log-log regression are valid and thus the specifications described below are appropriate given the data. To allow for any serial correlation, the results presented in Chapter 5 include robust standard errors that are clustered at the region level.

[12]For completeness it is noted that the Im-Pesaran-Shin test could only be conducted on 8 of the 9 panel series as the South East Region time series contains only 6 observations which is insufficient to carry out the test.

4.1. Base Model

The preliminary model takes the form:

$$ln(P_{ct}^{local}) \quad = \quad \phi\Big[ln(P_t^I) \cdot HHI_c^{Ave}\Big] + \alpha_c + \beta_t + u_{ct} \tag{4.1.1}$$

Where:

- $ln(P_{ct}^{local})$ is the log of the local cattle price in region c at time t;
- $ln(P_t^I)$ is the log of the international beef price at time t;
- HHI_c^{Ave} is the average (time-invariant) HHI in region c during the 2010-2015 period;
- α_c are region fixed effects;
- β_t are time fixed effects; and
- u_{ct} is an error term.

Here, the fixed effects are modelled using dummy variables for each region and month, with the base case being the Central Tablelands region in January 2010.

In Chapter 5 the results of the model are presented with and without fixed effects in order to examine the role played by these controls. In model variants without region fixed effects an additional HHI_c^{Ave} variable is included. Likewise, when time fixed effects are excluded the model is adjusted to include an $ln(P_t^I)$ variable. This ensures the estimated coefficient on the interaction term is not biased by the exclusion of the linear effect of either variable in the interaction term. In the full fixed effects model, the pure effects of HHI_c^{Ave} and $ln(P_t^I)$ are not included as the linear effects of these factors should be captured by the region and time fixed effects respectively and their inclusion would likely lead to collinearity.

The identifying assumption of this model is that the regions are price-takers in the international beef market; local cattle price is not endogenous to changes in international beef price. This exogeneity assumption seems plausible. According to ANZ (2015), Australian beef constitutes around only 4% of global beef production, and NSW accounts for roughly 20% of Australia's beef herd. It seems unlikely that any individual region in NSW has a sizeable impact on international beef prices given that NSW as a whole accounts for only approximately 0.8% of international beef trade.

4.2. Dynamic Models

In order to examine whether market structure influences the effect of past or future international beef prices on current local cattle price, lags and a lead variable are introduced to the model.

4.2.1. Lagged Effects. The backward-looking dynamic model is of the form:

$$ln(P_{ct}^{local}) = \sum_{s=0}^{3} \phi_s \left[ln(P_{t-s}^{I}) \cdot HHI_c^{Ave} \right] + \alpha_c + \beta_t + u_{ct} \tag{4.2.1}$$

Where $ln(P_{ct}^{local})$, $ln(P_t^I)$, HHI_c^{Ave}, α_c, β_t, and u_{ct} are as in the base model.

Here, lags of the interaction term are included in order to identify whether there are any significant lagged effects of international beef price on local cattle prices and whether any such effects are influenced by the degree of market concentration. 3 lags are chosen as the data is monthly and thus 3 lags encompass a full quarter of delayed effects. Lags of the pure $ln(P_t^I)$ are not included variable as this should be captured by the time fixed effects dummies.

4.2.2. Anticipation Effect. A single lead effect is then added to the lag model in order to check whether expectations as to future international beef prices have a significant impact on local cattle prices. This results in a dynamic model which is both forward- and backward-looking:

$$ln(P_{ct}^{local}) = \sum_{s=-1}^{3} \phi_s \left[ln(P_{t-s}^{I}) \cdot HHI_c^{Ave} \right] + \alpha_c + \beta_t + u_{ct} \tag{4.2.2}$$

Where $ln(P_{ct}^{local})$, $ln(P_t^I)$, HHI_c^{Ave}, α_c, β_t, and u_{ct} are as above.

It is expected that the one-month lead variable will capture any anticipation effects. As before, the lead and lags of the interaction term are included enabling examination of the extent to which pass-through of future, present and past international beef prices is affected by market concentration.

4.3. Exchange Rate Model

Finally, this paper seeks to determine whether the results from the above models are affected by the inclusion of an additional term which interacts market structure and the exchange rate. For consistency, the log of the TWI is interacted with the time-invariant HHI variable:

$$ln(P_{ct}^{local}) \quad = \quad \phi\Big[ln(P_t^I)\cdot HHI_c^{Ave}\Big] + \gamma\Big[ln(TWI_t)\cdot HHI_c^{Ave}\Big] + \alpha_c + \beta_t + u_{ct} \tag{4.3.1}$$

Where:

- $ln(P_{ct}^{local})$, $ln(P_t^I)$, HHI_c^{Ave}, α_c, β_t, and u_{ct} are as above; and
- $ln(TWI_t)$ is the log of the exchange rate, given by the TWI, at time t.

A pure exchange rate variable is not included as its linear effect should be accounted for in the time fixed effects. This model provides for examination of not only the impact of market structure on pass-through of international beef prices, but also its impact on exchange rate pass-through. This exchange rate version of the model can be extended to a dynamic model simply by adding the $(ln(TWI_t)\cdot HHI_c^{Ave})$ interaction term, along with any desired lags and leads, into models 4.2.1 and 4.2.2.

The results from these regressions are presented in Chapter 5.

CHAPTER 5

Results

This Chapter presents estimates of the average marginal effect of HHI on pass-through. In order to facilitate understanding of the estimated coefficients, it is first identified how pass-through would be estimated in a model without fixed effects. A simple model of pass-through without time and region fixed effects might take the form:

$$ln\big(P_{ct}^{local}\big) \quad = \quad \delta ln\big(P_t^I\big) + \phi\Big[ln\big(P_t^I\big) \cdot HHI_c^{Ave}\Big] + u_{ct}$$

In such a model, pass-through ($\hat{\rho}$) of international beef price to local cattle price is given by the estimated marginal effect of changes in international beef price:

$$\begin{aligned}\hat{\rho} \quad &= \quad \frac{\partial ln\big(P_{ct}^{local}\big)}{\partial ln\big(P_t^I\big)} \\ &= \quad \hat{\delta} + \hat{\phi} \cdot HHI_c^{Ave}\end{aligned}$$

In the fixed effects models presented in this paper, the $ln\big(P_t^I\big)$ term is not included as this is captured by the time fixed effects. It is therefore not possible to calculate the precise value of $\hat{\rho}$, but $\hat{\phi}$ can be interpreted as the reduction or increase in pass-through that results from a 1 point increase in HHI. It is important to note that, in the case of perfect pass-through, a 1% change in international beef price would lead to a 1% increase in local cattle price. A negative estimated $\hat{\phi}$ therefore indicates a reduction in pass-through of $\hat{\phi}$%, which is subtracted from a theoretical maximum increase in local cattle price of 1%.

5.1. Base Model

Table 3 presents the base model estimates of the average marginal effect of HHI on pass-through. Column (1) displays estimates where the change in the logarithm of international beef price, HHI and the interaction term are related to the change in the logarithm of local cattle price without controlling for time or region fixed effects. Column (2) adds region fixed effects to this regression and column (3) adds time fixed effects only. Column (4) presents the estimates of the full fixed effects model. In the model without any fixed effects, a small positive effect of HHI on pass-through of international beef prices is observed, although this coefficient is not statistically significant at any conventional level of significance. The fit of this model is very poor (R^2= 0.0018).

TABLE 3. *Baseline Estimates*

	ΔP_{ct}^{local}			
	(1) OLS	(2) OLS + Region FE	(3) OLS + Time FE	(4) OLS + FE
$ln\ P_t^I$	-0.0312904	-0.0022208		
	(0.0414612)	(0.0260518)		
$ln\ P_t^I * HHI_c^{Ave}$	0.0000176	-0.0002339	-0.0002344	-0.0002387
	(0.0003484)	(0.0002213)	(0.0002248)	(0.0002369)
HHI_c^{Ave}	0.0001049		0.0006008	
	(0.0007741)		(0.0005682)	
Time FE	No	No	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Region FE	No	Yes $^{\Psi\Psi\Psi}$	No	Yes $^{\Psi\Psi\Psi}$
Observations	581	581	581	581
Within R-sq	0.0018	0.0978	0.9056	0.9477

Note: The method of estimation is ordinary least squares in all columns. The columns vary according to the nature of the fixed effects methods employed. The numbers displayed in parentheses are robust standard errors that are clustered at the region level. The dependent variable is the change in the log of local cattle price. The explanatory variable is the interaction between the change in the log of the international beef price and the region's time-invariant HHI.
***,**,* indicate significance at the 1%, 5% and 10% levels, respectively.
$^{\Psi\Psi\Psi}$,$^{\Psi\Psi}$,$^{\Psi}$ indicate joint significance at the 1%, 5% and 10% levels, respectively.

As fixed effects are added in Columns (2)-(4), the fit of the model improves and the estimated coefficient on the interaction term becomes negative. This implies that an increase in HHI by 1 point reduces pass-through of international beef prices to local cattle prices. In all cases the magnitude of the estimated effect of the interaction term is small, although this is to be expected as a 1 point change is very small given the range of possible HHI values is $(0, 10000]$.

In order to contextualise the results, the effect of a 90 point increase in HHI is considered. This is the change in HHI that would result from the merger of 10 medium-sized farms, each with a market share of 1%, into a single entity with 10% market share. The estimated coefficient from the fixed effects model suggests that an increase in HHI of 90 points reduces pass-through by approximately 0.021%. In each model with fixed effects, it is found that the fixed effects are jointly significant and thus contribute to the explanatory power of the model. However, the estimated coefficients on the variables of interest are not statistically significant in any of the specifications in Table 3, indicating that HHI has no impact on pass-through of contemporaneous international beef prices.

One possible reason for these insignificant results is that the observed values of HHI are very small and span less than 3% of the theoretical range of HHI. This has the potential to attenuate the estimated effect. An alternative explanation as to why a significant effect of HHI on pass-through is not observed is that prices in the market are largely determined by domestic and supply-chain factors. It seems likely, in line with the literature discussed in section 2.3, that pass-through of international beef prices to local cattle prices is minimal due to the high degree of concentration among processors and retailers. If this vertical market structure effect is dominant then, consistent with the obtained results, pass-through will be small regardless of the level of competition among producers.

5.2. Dynamic Models

In Table 4 lags of the international beef price interaction term are added to check whether there are significant lagged effects on local cattle price.

TABLE 4. *Lagged and Anticipation Estimates*

	ΔP_{ct}^{local}	
	(1)	(2)
$ln\ P_{t+1}^{I} * HHI_c^{Ave}$		-0.000306 **
		(0.0000972)
$ln\ P_{t}^{I} * HHI_c^{Ave}$	-0.0001996	-0.0000948
	(0.0001286)	(0.0001213)
$ln\ P_{t-1}^{I} * HHI_c^{Ave}$	0.0000825	0.0000551
	(0.0001239)	(0.000128)
$ln\ P_{t-2}^{I} * HHI_c^{Ave}$	-0.0001481	-0.0001427
	(0.0001707)	(0.00017)
$ln\ P_{t-3}^{I} * HHI_c^{Ave}$	-0.0002949	-0.0002919
	(0.0002381)	(0.0002437)
Time FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Region FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Observations	554	545

Note: The method of estimation is in both columns is ordinary least squares with region and time fixed effects. The model in column (1) looks at the effect of 3 lags of the explanatory variables while the model in column (2) looks at a single lead/anticipation effect in addition to the 3 lags. The numbers displayed in parentheses are robust standard errors that are clustered at the region level. The dependent variable is the change in the log of local cattle price. The explanatory variable is the interaction between the change in the log of the international beef price and the region's time-invariant HHI.
***,**,* indicate significance at the 1%, 5% and 10% levels, respectively.
$^{\Psi\Psi\Psi}$,$^{\Psi\Psi}$,$^{\Psi}$ indicate joint significance at the 1%, 5% and 10% levels, respectively.

The estimated coefficients in column (1) indicate that introducing the lags to the model slightly reduces the estimated effect of HHI on pass-through of contemporaneous international beef prices. In this model, a 90 point increase in HHI is predicted to reduce pass-through by around 0.018%. Additionally, the estimated lagged effects vary in sign: pass-through of the previous month's international beef prices ($ln\ P^I_{t-1}$) is predicted to increase with HHI, while pass-through of older international beef prices ($ln\ P^I_{t-2}$and $ln\ P^I_{t-3}$) is predicted to fall as HHI increases. This variation in sign does not seem to have any logical explanation, although as none of the coefficients (contemporaneous or lagged) in the column (1) model are statistically significant, it is probable that HHI has no effect on pass-through of past or current prices. As in the base model, both the region and time fixed effects are found to be jointly significant.

In column (2) a one-month lead variable is added to the lagged model in order to identify any anticipation effects. This does not affect the significance of the region and time fixed effects, which are still jointly significantly different from zero at the 1% confidence level. The estimated coefficients obtained for the lagged and contemporaneous variables are similar in sign and significance to those in column (1). Hence again it is concluded that HHI has little or no effect on pass-through of current or past prices.

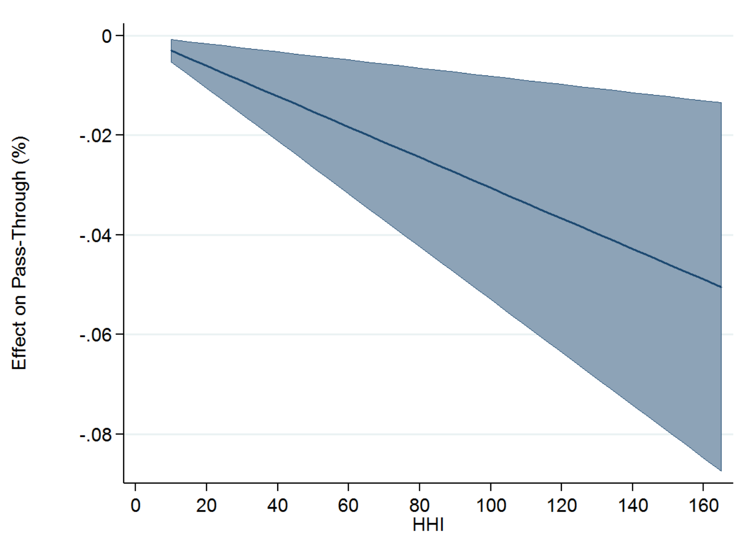
In contrast, the coefficient on the lead $(t+1)$ variable is negative and statistically significant at the 5% level. Hence it is found that pass-through of anticipated changes in future price is lower in more horizontally concentrated markets. Quantitatively, the estimated coefficient on the lead variable (-0.000306) implies that an increase in HHI of 90 points reduces pass-through of anticipated future international beef price by 0.028%. This finding is in line with the pass-through literature summarised in Chapter 2, suggesting that market structure has a similar effect on pass-through of anticipated international beef price to that of exchange rates, taxes and costs. However, the literature does not provide any guidance as to why this effect is limited to expected changes in international beef price and does not extend to current and past international beef prices. It could be that the nature of the cattle market is such that the effect of vertical market concentration attenuates pass-through for current and lagged prices but does not have the same impact on pass-through of anticipated prices. As the data do not extend to market concentration in the processing and retail industries, it is not possible to test that hypothesis in this analysis.

Figure 3 graphs the magnitude of the anticipation effect at various levels of market concentration. Graph (a) shows the estimated marginal effect of $ln\ P^I_{t+1}$ across the range of time invariant (average) HHIs observed in the sample. It shows the estimated linear effect of HHI on pass-through. For example, the model predicts that at the minimum observed average HHI value

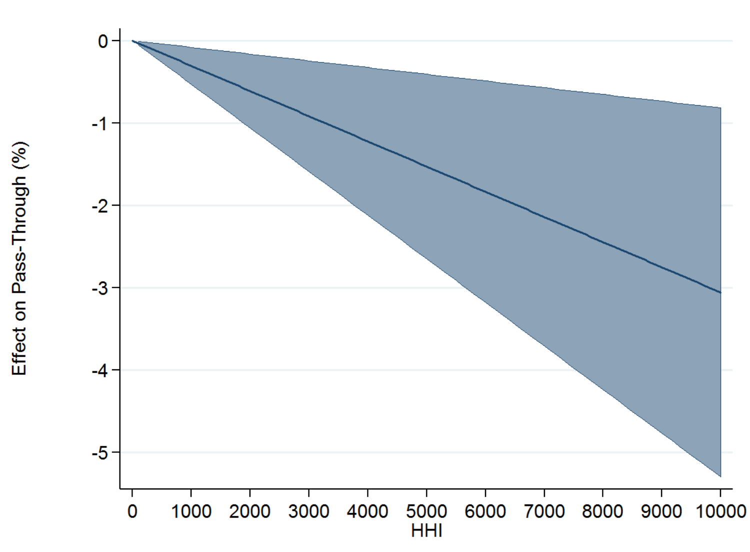
(HHI_c^{Ave}=11.14092), pass-through will be reduced by 0.003%. This negative effect increases in magnitude until at the highest average HHI observed (HHI_c^{Ave}=162.7807), pass-through is estimated to be reduced by 0.049%.

FIGURE 3. *The Impact of HHI on Pass-through of Anticipated Changes in P^I*

(a) Average Marginal Effect of Anticipated Changes in International Beef Price Across Observed Values of Time-Invariant HHI



(b) Average Marginal Effects of Anticipated Changes in International Beef Price Across All Theoretical Values of HHI



Note: These graphs correspond to the model estimated in Table 4, column (2). The shaded areas represent the 95% confidence interval around the estimated marginal effect.

Graph (b) extrapolates this marginal effect across the range of all theoretically possible HHI values $(0, 10000]$. At the largest time-variant HHI observed in the sample (HHI_{ct}=279.56) the predicted reduction in pass-through is equal to 0.085% and at the level of market concentration at which the ACCC will begin to identify horizontal market structure concerns (HHI=2000) (ACCC (2008)), the estimated reduction in pass-through is equal to 0.612%. Hence, if the marginal effect identified by the model holds for larger values of HHI, moderate levels of market concentration have the potential to reduce pass-through of anticipated international beef price changes by almost two-thirds.

Notably, the extrapolation seems to be invalid at large HHI values as for HHIs of over 3300 it predicts a reduction in pass-through of more than 1%. This would imply that, in response to a 1% increase in international beef price, market concentration causes local cattle price to fall. This seems to be an unreasonable prediction, as it is unlikely that greater market power on the part of producers would lead to lower prices for their cattle in response to an expected increase in international beef prices. In Chapter 6, Table 8, the results of a split sample robustness check are presented in an attempt to identify whether this linear relationship is indeed valid for higher HHI values.

5.3. Exchange Rate Models

In Table 5 an exchange rate interaction term ($ln(TWI_t) \cdot HHI_c^{Ave}$) is added to the models in order to identify whether market structure affects exchange rate pass-through in the beef industry. Adding the interaction term to the base model (column (1)) does not change the sign or significance of the estimated coefficient on the international beef price interaction term. The coefficient on the exchange rate interaction term is negative, suggesting an increase in HHI reduces pass-through of the exchange rate. However, the coefficient is not statistically significant.

In column (2) the model is estimated with 3 lags. Interestingly, using this specification it is found that both the contemporaneous (time t) interaction terms are statistically significant at the 5% level. The coefficient on the international beef price interaction term (-0.0002302) implies that an increase in HHI of 90 points will decrease pass-through of international beef prices by 0.021%. The magnitude of the predicted effect of HHI on pass-through of the exchange rate is greater; the estimated coefficient (-0.0042616) indicates that an increase of 90 points in HHI corresponds to a fall in pass-through of 0.384%. The estimated coefficient on the first lag of the exchange rate interaction term is positive and significant at the 10% level; however, none of the other lags are significantly different from zero.

TABLE 5. *Exchange Rate Estimates*

	ΔP_{ct}^{local}		
	(1)	(2)	(3)
$ln\ P_{t+1}^{I} * HHI_c^{Ave}$			-0.0003054 ***
			(0.0000496)
$ln\ P_{t}^{I} * HHI_c^{Ave}$	-0.0001531	-0.0002302 **	-0.0001343
	(0.0001454)	(0.0000914)	(0.0001074)
$ln\ P_{t-1}^{I} * HHI_c^{Ave}$		0.0000659	0.0001161
		(0.0001338)	(0.0001045)
$ln\ P_{t-2}^{I} * HHI_c^{Ave}$		-0.0000878	-0.0001393
		(0.0001375)	(0.0001471)
$ln\ P_{t-3}^{I} * HHI_c^{Ave}$		-0.0003271	-0.0002624
		(0.000216)	(0.0002149)
$ln(TWI_{t+1})\cdot HHI_c^{Ave}$			-0.0034709 ***
			(0.0010024)
$ln(TWI_{t})\cdot HHI_c^{Ave}$	-0.0007044	-0.0042616 **	-0.0009338
	(0.0008128)	(0.0018166)	(0.0010587)
$ln(TWI_{t-1})\cdot HHI_c^{Ave}$		0.0027171 *	0.0034211 **
		(0.0012908)	(0.0014073)
$ln(TWI_{t-2})\cdot HHI_c^{Ave}$		0.0011921	0.0008773
		(0.000847)	(0.0009302)
$ln(TWI_{t-3})\cdot HHI_c^{Ave}$		0.0003074	-0.0001914
		(0.0008293)	(0.0006235)
Time FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Region FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Observations	581	554	545

Note: The method of estimation is in all columns is ordinary least squares with region and time fixed effects. The model in column (1) looks at the contemporaneous effects of the interaction terms, the model in column (2) looks at the effect of 3 lags of the explanatory variables and the model in column (3) looks at a single period lead/anticipation effect in addition to the 3 lags. The numbers displayed in parentheses are robust standard errors that are clustered at the region level. The dependent variable is the change in the log of local cattle price. The explanatory variables are the interaction between the change in the log of the international beef price and the region's time-invariant HHI and the interaction between the change in the log of the Trade Weighted Index and the region's time-invariant HHI.
***,**,* indicate significance at the 1%, 5% and 10% levels, respectively.
$^{\Psi\Psi\Psi}$,$^{\Psi\Psi}$,$^{\Psi}$ indicate joint significance at the 1%, 5% and 10% levels, respectively.

When a lead variable is added to the model (column (3)) contemporaneous effects are no longer found to be statistically significant. In this specification it is again found that the only lagged variable that is statistically different from zero is the first lag of the exchange rate interaction term. The estimated effect of the $t-1$ exchange rate term is positive and significant at the 5% level.

Negative estimates that are statistically significant at the 1% level are obtained for both lead $(t+1)$ interaction terms. Again, the magnitude of the estimated coefficient on the anticipated exchange rate variable (-0.0034709) is larger than that of the anticipated international beef price variable (-0.0003054). These estimates suggest that an increase in HHI of 90 points reduces pass-through of international beef prices by 0.027%, while the same increase in market concentration corresponds to a reduction in pass-through of the exchange rate by 0.312%. This indicates that market concentration has a larger impact on pass-through of exchange rates than pass-through of international beef prices.

The literature described in Chapter 2 gives rise to two possible explanations for this discrepancy in magnitude of the estimated effects. First, it could be that domestic sales are more prevalent than export sales in NSW, resulting in a low pass-through rate of international beef prices. In this scenario, pass-through of international beef prices would likely be small even at low values of HHI, attenuating the observed effect of changes in market concentration. Alternatively, exchange rate pass-through may be generally higher than that of international beef prices as the exchange rate directly affects the cost of production. A change in the exchange rate will influence the price of imported inputs regardless of whether or not production is export-oriented. In contrast, the effect of a change in international beef prices on local cattle prices is indirect and operates via export price changes. If this is the case then the higher level of pass-through exhibited by exchange rates would permit greater variation as a consequence of market concentration.

Interestingly, in both column (2) and column (3) the coefficients on the lead and first lag of the exchange rate interaction term have opposite signs. This result has no ready explanation, as it seems odd that market concentration would lead to a reduction in pass-through of anticipated changes in international beef price and at the same time increase pass-through of the previous month's international beef price. As a robustness check, the same model is estimated using the US$ to AU$ exchange rate[13] instead of TWI in Chapter 6. This check yields very similar results (see Table 10).

In Chapter 6 we present Table 10 along with the results of further robustness checks.

[13] Data as to the end of the month US$ to AU$ exchange rate were obtained from the Reserve Bank of Australia's historical database: http://www.rba.gov.au/statistics/historical-data.html.

CHAPTER 6

Robustness Checks

As described in section 3.5, the results presented in Chapter 5 are obtained using an average, time-invariant HHI measure as an indicator of market structure in each region. In Table 6 the results of the base model are presented using different constructions of HHI. Column (1) displays the results of the base model using the average 2010-2015 HHI as used in the above analysis. In column (2), the HHI of each region in 2010 (the first year of the dataset) is used as the time-invariant measure. No difference in sign or significance is observed between the two, indicating that the choice of average or initial time-invariant HHI has little impact on the results of this analysis.

In columns (3) and (4) the method used to calculate the HHI for each region is altered. The generally low HHIs observed in the data may give rise to the concern that simply using beef cattle herd size as a measure of market share may not adequately capture the market power of beef producers. In particular, anecdotal evidence suggests that there are many cattle owners who have small herds that are kept for pleasure rather than profit. These holdings are often termed “hobby farms” and likely do not engage in the market frequently as their cattle tend to be treated more like pets than livestock. Despite perhaps not being frequent players in the cattle market, “hobby farmers” must still report their cattle herd numbers to the LLS and are therefore captured in the HHI measure used throughout Chapter 5. In order to ensure that these results are not obtained using a measure of market concentration that is biased downwards by inclusion of these “hobby farms”, an alternative HHI is constructed that excludes herds of less than 10 beef cattle. Column (3) presents estimates obtained using the time-invariant average from 2010-2015 of this alternative HHI measure. Column (4) shows the results when each region’s alternative HHI excluding “hobby farms” for 2010 is used. Neither alternative measure changes the sign or significance of the baseline estimates, and the estimated magnitudes are very similar to those in columns (1) and (2), suggesting that “hobby farms” do not significantly bias the HHI measure used in Chapter 5. This is perhaps unsurprising, as farms with less than 10 cattle contribute only slightly to total regional herd size. Unless such “hobby farms” make up a large number of the holdings in each region, they likely play only a marginal role in determining HHI.

TABLE 6. *Robustness Check I: Varying Constructions of HHI*

	ΔP_{ct}^{local}			
	(1)	(2)	(3)	(4)
$ln\ P_t^I * HHI_c$	-0.0002387	-0.0001285	-0.0002335	-0.0001263
	(0.0002369)	(0.001246)	(0.0002328)	(0.0001226)
Time FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Region FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Observations	581	581	581	581

Note: The method of estimation is ordinary least squares in all columns. Each uses the base model outlined in equation 4.1.1. The columns vary according to the time-invariant HHI measure used. Column (1) shows the estimates obtained using average HHI as used throughout Chapter 5. The estimates in column (2) are obtained using each region's initial (2010) HHI. Columns (3) and (4) use HHIs obtained by first dropping all beef cattle herds of less than 10 ("hobby farms") from the dataset and then calculating HHI according to the process outlined in section 3.1. In column (3) the 2010-2015 average of HHI excluding "hobby farms" is used, while column (4) displays the estimates obtained when initial (2010) HHI excluding "hobby farms" is used.

The numbers displayed in parentheses are robust standard errors that are clustered at the region level. The dependent variable is the change in the log of local cattle price. The explanatory variable is the interaction between the change in the log of the international beef price and HHI.

***,**,* indicate significance at the 1%, 5% and 10% levels, respectively.

$^{\Psi\Psi\Psi}$,$^{\Psi\Psi}$,$^{\Psi}$ indicate joint significance at the 1%, 5% and 10% levels, respectively.

Table 7 Panel A shows that there continues to be a significant effect on pass-through of anticipated international beef prices in the dynamic models when the top and bottom 5% of variation in local cattle price is excluded. In fact, when these extreme values of the dependent variable are excluded, the significance of the results increases. The contemporaneous effect of the interaction term becomes significant in the lagged model (column (2)), as does the first lag ($t-1$). The coefficient on the lead interaction term (column (3)) becomes significant at the 1% level (in contrast with the 5% level as shown in Table 4) and the $t-1$ lag significant at the 5% level. This adds weight to the finding that increasing market concentration reduces pass-through of anticipated international beef price changes.

In Table 7 Panel B, estimates obtained by excluding Hadi multivariate outliers (see Hadi (1992, 1993)) identified at a confidence level of 5% are reported. Excluding these outliers reduces the significance of most of the estimated coefficients. In fact, when these outliers are excluded none of the coefficients on the lead or lagged variables are statistically significant. However, excluding Hadi multivariate outliers increases the significance of the estimated coefficient on the contemporaneous (time t) interaction term, which is negative and becomes statistically significant at the 10% level.

TABLE 7. *Robustness Check II: Excluding Outliers*

	ΔP_{ct}^{local}		
	(1)	(2)	(3)
Panel A: Excluding extreme values of P_{ct}^{local}			
$ln\ P_{t+1}^{I} * HHI_c^{Ave}$			-0.0005661 ***
			(0.0001292)
$ln\ P_{t}^{I} * HHI_c^{Ave}$	-0.0002172	-0.0002648 *	-0.0000156
	(0.0001481)	(0.0001423)	(0.0001076)
$ln\ P_{t-1}^{I} * HHI_c^{Ave}$		0.000255 **	0.0002752 **
		(0.0000906)	(0.0000927)
$ln\ P_{t-2}^{I} * HHI_c^{Ave}$		0.000000	0.0000172
		(0.0001405)	(0.0001372)
$ln\ P_{t-3}^{I} * HHI_c^{Ave}$		-0.0000975	-0.0001102
		(0.0000925)	(0.000094)
Time FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Region FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Observations	521	498	496
Panel B: Excluding Hadi Multivariate Outliers			
$ln\ P_{t+1}^{I} * HHI_c^{Ave}$			0.0027408
			(0.0028203)
$ln\ P_{t}^{I} * HHI_c^{Ave}$	-0.0010924	-0.0006217	-0.005778 *
	(0.0011668)	(0.0028928)	(0.0030171)
$ln\ P_{t-1}^{I} * HHI_c^{Ave}$		0.0005386	0.0001038
		(0.0006848)	(0.0003952)
$ln\ P_{t-2}^{I} * HHI_c^{Ave}$		0.0004005	0.0007898
		(0.0003984)	(0.0004711)
$ln\ P_{t-3}^{I} * HHI_c^{Ave}$		-0.0002543	-0.0001837
		(0.000447)	(0.0006063)
Time FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Region FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Observations	510	447	425

Note: The method of estimation is in both columns is ordinary least squares with region and time fixed effects. The model in column (1) is the base model. The model in column (2) looks at the effect of 3 lags of the explanatory variables while the model in column (3) looks at a single lead/anticipation effect in addition to the 3 lags. The numbers displayed in parentheses are robust standard errors that are clustered at the region level. The dependent variable is the change in the log of local cattle price. The explanatory variable is the interaction between the change in the log of the international beef price and the region's time-invariant HHI. In Panel A the top and bottom 5% of variation in local cattle price is excluded. In Panel B outliers identified using the methods described in Hadi (1992, 1993) are excluded.
***,**,* indicate significance at the 1%, 5% and 10% levels, respectively.
$^{\Psi\Psi\Psi}$,$^{\Psi\Psi}$,$^{\Psi}$ indicate joint significance at the 1%, 5% and 10% levels, respectively.

These changes in significance could indicate that the results in Chapter 5 are largely driven by extreme variation in the explanatory terms: for instance, volatility in international beef prices. Alternatively, the reduction in significance could be due to the fact that, after excluding the multivariate outliers, much of the observed variation in HHI is eliminated. For example, the Hadi process identifies all observations from the Riverina region as outliers. This is because the 2010-2015 average HHI for that region is 106 points higher than the second-most concentrated region. Excluding all observations from the Riverina region reduces by more than half the observed variation in HHI, which likely attenuates the magnitude and significance of the estimated effects.

TABLE 8. *Robustness Check III: Sample Split*

	ΔP_{ct}^{local}		
	(1)	(2)	(3)
Panel A: Regions with HHI_c^{Ave} > median			
$ln\ P_{t+1}^I * HHI_c^{Ave}$			-0.000126
			(0.0001507)
$ln\ P_t^I * HHI_c^{Ave}$	-0.000203	-0.0002391	-0.0002092
	(0.0001637)	(0.0001146)	(0.0001864)
$ln\ P_{t-1}^I * HHI_c^{Ave}$		0.0001558	0.000147
		(0.0002083)	(0.000185)
$ln\ P_{t-2}^I * HHI_c^{Ave}$		0.0000000	0.0000000
		(0.0001533)	(0.0001562)
$ln\ P_{t-3}^I * HHI_c^{Ave}$		-0.0001231	-0.0001313
		(0.0001592)	(0.0001396)
Time FE	Yes	Yes $^{\Psi\Psi}$	Yes $^{\Psi\Psi}$
Region FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Observations	287	275	271
Panel B: Regions with $HHI_c^{Ave} \leq$ median			
$ln\ P_{t+1}^I * HHI_c^{Ave}$			-0.0001688
			(0.0028317)
$ln\ P_t^I * HHI_c^{Ave}$	-0.006931	-0.0028795	-0.0042313
	(0.0071063)	(0.0046321)	(0.0036625)
$ln\ P_{t-1}^I * HHI_c^{Ave}$		-0.0038626	-0.0036576
		(0.0025901)	(0.0028444)
$ln\ P_{t-2}^I * HHI_c^{Ave}$		-0.0065484 *	-0.0065769 *
		(0.0029238)	(0.0028822)
$ln\ P_{t-3}^I * HHI_c^{Ave}$		-0.0044487	-0.0054064
		(0.0078509)	(0.0078164)
Time FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Region FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi}$	Yes $^{\Psi\Psi}$
Observations	294	279	274

Note: The method of estimation is in both columns is ordinary least squares with region and time fixed effects. In Panel A the base case is the Murray region in January 2010. In Panel B the base case is the Central Tablelands in January 2010. The model in column (1) is the base model. The model in column (2) looks at the effect of 3 lags of the explanatory variables while the model in column (3) looks at a single lead/anticipation effect in addition to the 3 lags. The numbers displayed in parentheses are robust standard errors that are clustered at the region level. The dependent variable is the change in the log of local cattle price. The explanatory variable is the interaction between the change in the log of the international beef price and the region's time-invariant HHI.

***,**,* indicate significance at the 1%, 5% and 10% levels, respectively.

$^{\Psi\Psi\Psi}$,$^{\Psi\Psi}$,$^{\Psi}$ indicate joint significance at the 1%, 5% and 10% levels, respectively.

Another interesting issue that can be explored with the data is whether the linear model is appropriate for identifying the effect of HHI on pass-through. One might expect that the relationship between market concentration and pass-through is different at high HHIs than that at low HHIs. To investigate this, the sample is split at the median time-invariant HHI and the base and dynamic models are estimated for each subsample. Table 8 Panel A shows the estimated coefficients for regions with HHI above the median. While the signs and magnitudes are similar to those reported for the full dataset, none of the estimated coefficients are significant.

Similar results are obtained for the low HHI regions. These are presented in Panel B. Notably, the estimated coefficients for the below median subsample tend to be larger than those for the high HHI group. This may indicate that increasing market concentration reduces pass-through at a decreasing rate and therefore the linear model may not be appropriate. However, aside from the estimated coefficient on the 2 month lagged variable $(t-2)$ for the low HHI subsample, all the estimated effects are insignificant at any conventional level of significance. This means that despite the differences in magnitude of the estimated coefficients across the two groups, only the effect of the $(t-2)$ lagged interaction term in Panel B is significantly different from zero. It is therefore difficult to draw a definite conclusion as to whether or not the linear model is suitable.

Table 9. *Robustness Check IV: Using FAO Index*

	ΔP_{ct}^{local}		
	(1)	(2)	(3)
$ln\ P_{t+1}^{I} * HHI_c^{Ave}$			0.0011137
			(0.0014452)
$ln\ P_{t}^{I} * HHI_c^{Ave}$	0.0008022	0.001016	-0.0005256
	(0.0007123)	(0.0014476)	(0.0008178)
$ln\ P_{t-1}^{I} * HHI_c^{Ave}$		0.0005591	0.0014285 *
		(0.0010893)	(0.0006252)
$ln\ P_{t-2}^{I} * HHI_c^{Ave}$		-0.0007993 **	-0.0020961 ***
		(0.0003382)	(0.0003102)
$ln\ P_{t-3}^{I} * HHI_c^{Ave}$		-0.0000899	0.0008341
		(0.0004107)	(0.0005959)
Time FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Region FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Observations	581	554	545

Note: The method of estimation is in both columns is ordinary least squares with region and time fixed effects. The model in column (1) is the base model. The model in column (2) looks at the effect of 3 lags of the explanatory variables while the model in column (3) looks at a single lead/anticipation effect in addition to the 3 lags. The numbers displayed in parentheses are robust standard errors that are clustered at the region level. The dependent variable is the change in the log of local cattle price. The explanatory variable is the interaction between the change in the log of the UN Food and Agriculture Organisation bovine meat price index and the region's average HHI over the 2010-2015 period.
***,**,* indicate significance at the 1%, 5% and 10% levels, respectively.
$^{\Psi\Psi\Psi}$,$^{\Psi\Psi}$,$^{\Psi}$ indicate joint significance at the 1%, 5% and 10% levels, respectively.

Table 9 shows the estimates obtained from using the UN Food and Agriculture Organisation's ('UNFAO') bovine meat price index FAO (2016) as the international beef price variable used in the model's interaction terms. It indicates that the findings in Chapter 5 are not robust to changes in the measurement of international beef price. The estimated coefficient on the lead variable using the UNFAO measure is positive and not statistically significant. Additionally, when the UNFAO data are used the first and second lags become significant at the 10% and 1% levels, respectively. These discrepancies could be due to differences in construction: the UNFAO index weights world prices according to estimated trade flows whereas the measure used in this paper and described in section 3.3 weights according to actual trade volumes. Alternatively, the potential for reporting errors in the UN Comtrade value and volume data used to construct the measure used throughout Chapter 5 may lead to divergences between the two measures of international beef price, explaining the variation in results obtained.

Finally, Table 10 presents estimates of the exchange rate model obtained using the US$ to AU$ exchange rate instead of the TWI. The estimates are very similar in sign, significance and magnitude to those presented above, indicating that the results of this analysis are robust to changes in exchange rate measure. In fact, the results become slightly more statistically significant when the US$ to AU$ model is used. The United States is home to many prominent manufacturers of agricultural inputs and is also a major importer of Australian beef (MLA (2016)). These factors may mean that pass-through of the US$ to AU$ exchange rate is higher than pass-through of the TWI, which could explain the more significant results of HHI on pass-through that are obtained using the US$ to AU$ measure.

TABLE 10. *Robustness Check V: Using US$ to AU$ Exchange Rate*

	ΔP_{ct}^{local}		
	(1)	(2)	(3)
$ln\ P_{t+1}^I * HHI_c^{Ave}$			-0.000308 ***
			(0.0000493)
$ln\ P_t^I * HHI_c^{Ave}$	-0.0001535	-0.0002218 **	-0.0001453
	(0.0001498)	(0.0000883)	(0.0001108)
$ln\ P_{t-1}^I * HHI_c^{Ave}$		0.000081	0.0001448
		(0.0001354)	(0.0001031)
$ln\ P_{t-2}^I * HHI_c^{Ave}$		-0.0000797	-0.0001408
		(0.0001396)	(0.0001499)
$ln\ P_{t-3}^I * HHI_c^{Ave}$		-0.0003373	-0.0002824
		(0.0002229)	(0.000224)
$ln(e_{t+1}) \cdot HHI_c^{Ave}$			-0.002277 ***
			(0.0006148)
$ln(e_t) \cdot HHI_c^{Ave}$	-0.0004526	-0.0028282 *	-0.0006606
	(0.0005)	(0.0013153)	(0.0008711)
$ln(e_{t-1}) \cdot HHI_c^{Ave}$		0.0019559 *	0.0026497 **
		(0.0009182)	(0.0010075)
$ln(e_{t-2}) \cdot HHI_c^{Ave}$		0.0007196	0.0006303
		(0.0005592)	(0.0005458)
$ln(e_{t-3}) \cdot HHI_c^{Ave}$		0.0000444	-0.0006083
		(0.0006506)	(0.0004091)
Time FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Region FE	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$	Yes $^{\Psi\Psi\Psi}$
Observations	581	554	545

Note: The method of estimation is in all columns is ordinary least squares with region and time fixed effects. The model in column (1) looks at the contemporaneous effects of the interaction terms, the model in column (2) looks at the effect of 3 lags of the explanatory variables and the model in column (3) looks at a single period lead/anticipation effect in addition to the 3 lags. The numbers displayed in parentheses are robust standard errors that are clustered at the region level. The dependent variable is the change in the log of local cattle price. The explanatory variables are the interaction between the change in the log of the international beef price and the region's average HHI over the 2010-2015 period and the interaction between the change in the log of the US$ to AU$ exchange rate and the time-invariant HHI.
***,**,* indicate significance at the 1%, 5% and 10% levels, respectively.
$^{\Psi\Psi\Psi}$,$^{\Psi\Psi}$,$^{\Psi}$ indicate joint significance at the 1%, 5% and 10% levels, respectively.

CHAPTER 7

Conclusion

This empirical thesis examined the effect of market structure on pass-through of international beef prices to local cattle prices in NSW. It exploited a unique dataset containing unusually disaggregated beef cattle herd size data, allowing the thesis to explore the impacts of market concentration at a regional level. To do this, an ordinary least squares methodology with time and region fixed effects was employed.

The paper's main finding was that market concentration has no significant impact on pass-through of contemporaneous or lagged international beef prices, but reduces pass-through of anticipated changes in future international beef price. Additionally it found that market concentration has a negative impact on pass-through of expected changes in the exchange rate, and that the magnitude of this effect is larger than that on pass-through of anticipated international beef prices. The paper posited that this difference in magnitude may be due to the direct link between exchange rates and input prices leading to generally higher levels of exchange rate pass-through. In contrast, international beef prices affect local cattle prices indirectly (via changes in export prices), which may result in generally lower levels of pass-through and attenuate the influence of market structure.

The thesis documented that these findings are robust to alternative market concentration measures, exchange rate measures and to the exclusion of dependent variable outliers. It also explored the appropriateness of the linear model used, although splitting the sample at the median level of market concentration yielded no firm conclusions in this regard. Unfortunately, this thesis' findings are not robust to different measures of international beef price or Hadi multivariate outlier exclusion. It was argued that this could be due to the fact that excluding multivariate outliers in this way results in a large reduction in variation in the independent variables, particularly time-invariant HHI.

Despite these robustness concerns, this paper's finding that the impact of producer concentration on pass-through is limited to pass-through of anticipated international beef prices is intriguing. The literature regarding pass-through does not shed much light on why this might be the case. It could simply reflect a purely anticipatory effect of international beef prices on local cattle prices.

Alternatively, it was posited that this might be due to some feature of vertical market structure in the beef industry (most likely oligopsonistic behaviour by beef processors and/or retailers) which stymies pass-through of contemporaneous and lagged price effects, attenuating the impact of horizontal market concentration among producers, but is sensitive to anticipated international beef price changes.

The results of this thesis have several policy implications. First, the small magnitude of the estimated effects indicates that market concentration among producers in the beef cattle industry does not lead to substantial price distortion. Thus, any measures taken to address issues of market power in the industry need not include producers. Secondly, the finding that producer concentration does not influence pass-through of contemporaneous or past international beef prices may be indicative of the exercise of market power elsewhere in the beef supply chain. There is likely price distortion being introduced through oligopsonistic behaviour by processors and/or retailers, meaning policymakers would benefit most from focusing on those areas of the industry. Notably, if the trend towards vertical integration in the beef industry continues, this may actually reduce the magnitude of any distortion by reducing the number of times a margin is applied throughout the beef processing and retail stages (Hong and Li (2013)).

Investigation of the existence and extent of oligopsonistic behaviour in the beef industry is an avenue for future research. This thesis sought to advance understanding in this area from the embryo to infancy. Although the behaviour and degree of concentration of beef processors and retailers is beyond the scope of this analysis, the model used in this thesis could be extended to include other aspects of the beef supply chain. Such a model could provide extensive insights into the interplay between the horizontal and vertical market structure of the industry and develop understanding of beef industry market structure beyond childhood into adolescence. An extended model of a similar nature to that adopted in Hong and Li (2013) would shed light on the extent to which rigidities in the beef processing and retail industries affect pass-through of international beef prices. It would also provide policymakers with further guidance as to whether price distortion is introduced to the beef industry as a result of market structure and, if so, at what stage of the supply chain this occurs.

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