Estimating the Costs and Benefits of Cattle Traceability: the Case of the Québec Cattle Traceability System

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Following recent food safety scares, there has been a surge in the interest for the identification and the traceability of cattle. For instance, in the United States, the current goal of the National Animal Identification System (NAIS) is that 70 % of the premises are registered in the NAIS by the end of 2009 (USDA/APHID 2008). In Canada, animal identification is compulsory since 2002. At the same time, the government of the province of Québec adopted requirements than prescribed by the Canadian regulation. It is claimed that cattle in Québec are not only identified but they are also traceable. That is, all the movements of cattle are recorded from the birth until the death.

In the United States, the implementation of the NAIS has faced resistance from industry organizations. The main concerns of farmers is that the costs of such a system would outweigh the benefits. No comprehensive cost-benefit analysis of the NAIS currently exists to our knowledge. The USDA estimate that implementing farm-to-slaughter traceability would cost approximately $ 500 millions over six years (Bailey, Robb, and Checketts 2005). The benefits of animal identification and traceability are difficult to measure as they largely depend on the occurrence on disease outbreaks and food safety incidents or the subjective evaluation that traceability leads to safer meat in the market because firms are no longer anonymous. Whether the benefits outweigh the costs is unknown. The distribution of the benefits and costs in the supply chain is also unknown.

In this paper, we lay the foundation for estimating of the effects of the Québec cattle traceability system. First, we present background information on the Canadian (including Québec) cattle industry. We review the major issues that the Canadian cattle industry faces. We discuss the implementation of the cattle identification system Canada and the implementation of the cattle traceability system in Québec. Also, we review the effects on the Canadian cattle and beef industry of the discovery of a case of BSE in Alberta in 2003. Second, we develop a theoretical model to derive testable hypotheses on the effects of mandatory traceability on the price and the quantity of cattle produced in Québec. Third, we discuss the approach and the data that we will use estimate the effects of cattle traceability in Québec.

The Canadian cattle and meat industry

We review in this section important features of the Canadian cattle and beef industry. We discuss the major changes in the industry over the last decade. Then, we describe the cattle identification system in Canada and the traceability in Québec. Finally, we review the effects of the discovery of cases of BSE in Canada.

The Canadian cattle and beef industry

The cattle and calves industry is the largest agricultural sector in Canada, accounting for 15.4% of total cash receipt of Canadian farms in 2007 (Statisitics Canada 2008). Table 1 shows the inventory of cattle by provinces in Canada on January 1st 2007. The Atlantic provinces are small producers of cattle. Québec and Ontario are the main producing regions of dairy products in Canada and have the largest herds of milk cows and dairy heifers.

The production of cattle for beef is mainly located in the prairies, comprised of Alberta, Saskatchewan and Manitoba. 72% of the cattle in Canada are found in the prairies provinces. Alberta is the largest producing province and accounts for 41% of the total number of cattle in Canada. British Columbia is not a major producer of dairy cattle and beef cattle.

Figure 1 shows the total number of cattle slaughtered in federally inspected slaughterhouses in Canada and the number of cattle slaughtered in the provinces of

Table 1. The Canadian cattle inventory by province on January 1st 2007 ('000 head)

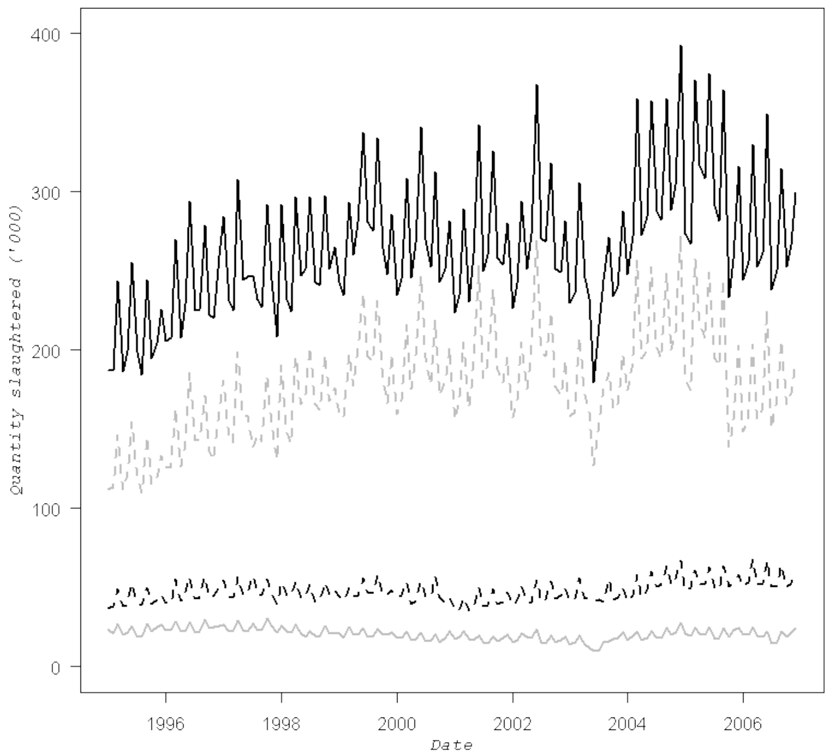
	Bulls	Milk cows	Beef cows	Dairy heifers	Beef heifers	Steers	Calves	Cattle
Atlantic	4	63	64	32	26	26	78	292
Québec	14	367	235	158	62	111	448	1 395
Ontario	24	321	369	181	214	327	519	1 953
Manitoba	29	45	612	21	177	95	562	1 540
Saskatchewan	70	30	1,480	14	295	175	1 366	3 430
Alberta	108	83	2 076	38	1 119	1 000	2 046	6 470
B.C.	16	72	277	37	65	57	282	805
Canada	264	980	5,113	480	1 958	1 791	5 301	15 885

Notes: The data were obtained from Statistics Canada (Statistics Canada 2007). Atlantic provinces are: Newfoundland and Labrador, Nova Scotia, Prince Edward Island, and New Brunswick. A bull is an uncastrated male bovine. A heifer is a female cow that has never borne young. A steer is a castrated male bovine.

Alberta, Ontario and Québec and Atlantic provinces[1]. Federally registered slaughterhouses are facilities that export meat in foreign countries or other provinces. These facilities are under the scrutinity of the Canadian Food and Inspection Agency (CFIA). Federally registered slaughterhouse must have a Hazard Analysis and Critical Control Point (HACCP) system in place. The total number of cattle slaughtered in federally inspected facilities in Canada has continuously increased over the last decade. Only in 2003, when BSE was first discovered in Canada that the number of slaughtered animals Canada significantly decreased.

A majority of cattle are slaughtered in Alberta. Nearly 80 % of the slaughter occurs in two Albertan abattoirs, Cargill Limited (Cargill) in High River and Lakeside Packers Ltd. (IBP-Tyson) at Brooks. Almost 75 % of Québec cattle are slaughtered in Ontario (Jacob, Doyon, and Librowicz 2003). The only remaining slaughterhouse in Québec, Colbex, is own by the Fédération des Producteurs de Bovins du Québec,

[1]Data for federally registered establishments were not disaggregated for Québec and the Atlantic provinces.



Note: The data were obtained from the annual review of the red meat industry by Agriculture and Agri-Food Canada (Agriculture and Agri-Food Canada 2007). The black line is the total quantity of cattle slaughtered in Canada in federally inspected slaughterhouse, the dashed grey line is the number of cattle slaughtered in Alberta, the dashed black line is the number of cattle slaughtered in Ontario and the grey line is the number of cattle slaughtered in Québec and Atlantic provinces.

Figure 1. Number of Cattle ('000) Slaughtered in Federally Inspected Establishments in Canada by Month

the provincial producer association. The slaughterhouse is the only plant that still processes cull cows in Eastern Canada since the Gencor in Ontario closed in April 2008 (Thompson 2008).

The American and the Canadian cattle and beef markets are well integrated. Vollrath and Hallahan (2006) find that Canada-United States cattle and meat markets are neither perfectly integrated nor completely segmented. For steers, the point estimate of post-CUSTA/NAFTA degree of market integration is 0.66, meaning that 66% of changes in prices in one market are transmitted in the other market.[2] The degree of market integration for beef loin and chuck was lower at 0.33. This lower degree of integration for meet can be partially explained by the mutual non-recognition by Canada and the United States of the grades given to meat by the partner country. That is, Canada beef cannot received USDA quality grades in the United States while American beef sold in Canada cannot be graded A, AA or AAA (Vollrath and Hallahan 2006).

Table 2 shows the number of cattle exported to the United States by province from 1998 to 2006. Alberta is the largest exporting province, followed by Manitoba and Ontario. Note that by comparing the numbers in figure 1 to the numbers in table 2 that more cattle are exported from Canada to the United States than slaughtered in Canada, except for 2003 and 2004 following the BSE crisis. The number of cattle imported in Canada from the United States is small compared to the quantity of cattle exported from Canada to the United States.[3]

Canada is a net exporter of beef to the United States. The 2003 case of mad cow affected the volume of beef exported as countries, United States among others,

[2] The Canada-U.S. Free Trade Agreement (CUSTA) was implemented in 1989 and the North-American Free Trade Agreement (NAFTA) implemented in 1994 included Mexico in the free trade agreement between Canada and the United-States.

[3] The number of slaughter cattle imported in Canada from the United States from 1996 to 2004 is: 1996 - 42 877, 1997 - 37 299, 1998 - 34 322, 1999 - 40 123, 2000 - 40 323, 2001 - 30 718, 2002 - 36 762, 2003 - 13 721, and 2004 - 6 (Agriculture and Agri-Food Canada 2007). No data are available for 2005 and 2006.

Table 2. Slaughter cattle exported to the United States by provinces ('000 head)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Atlantic	0	0	0	0	1	3	4	0	0	0
Québec	0	31	0	0	2	0	0	0	3	5
Ontario	28	156	142	161	231	248	118	0	32	49
Manitoba	138	282	202	197	289	313	100	0	50	84
Saskatchewan	75	31	22	22	32	35	11	0	6	9
Alberta	520	541	377	373	461	387	136	0	213	537
B.C.	31	34	57	46	49	79	20	0	6	21
Canada	1 108	1 077	801	799	1 066	1 065	390	0	310	704

Source: Annual review of the red meat industry by Agriculture and Agri-Food Canada (Agriculture and Agri-Food Canada 2007).

banned Canadian beef from their market. In 2007, the volume of beef imported from Canada represented 2.8% of U.S. beef consumption (Economic Research Service 2008).[4] The value of beef traded between Canada and the United States has been larger than the value of cattle traded between the two countries since the 2003 mad cow. Still, technical trade barriers such as the different grading systems in the two countries possibly dampen the volume of beef traded between Canada and the U.S. Exported cattle are also subject to technical restrictions. For instance, pregnancy tests for heifers are performed, and age and brand are verified at the border. Rude, Carlberg, and Pellow (2007) use a $5 per cwt border fee per cattle in their simulation model to account for the tests conducted on cattle at the border.

The Canadian cattle and calves industry is small compared to its American counterpart. Table 3 compares the Canadian cattle and beef industry to the American beef and cattle industry. Overall, the Canadian cattle industry is 10-15% the size of the American industry.

[4]From 2002 to 2006, the share of beef imported from Canada in U.S. beef consumption was 3.9%, 2.7%, 3.8%, 3.9%, and 3.0% (Economic Research Service 2008).

Table 3. Comparison of the Canadian and U.S. cattle/beef industries

			2002	2003	2004	2005	2006
Number of farms							
		Canada	118 510	116 785	116 520	116 775	108 870
		U.S.	1 036 430	1 013 570	989 460	982 510	971 400
Jan 1 inventory ('000 head)							
		Canada	13 762	12 488	14 653	15 063	14 830
		U.S.	96 704	96 100	94 882	95 848	96 702
Cattle Slaughter ('000 head)							
	Canada	Cattle	3 457	3 157	3 925	3 932	3 544
		Calves	293	331	353	359	343
	U.S.	Cattle	35 731	35 647	32 880	32 536	33 850
		Calves	1 044	1 039	879	772	748
Beef Production ('000 metric tons)							
		Canada	1 256	1 143	1 453	1 482	na
		U.S.	12 314	11 955	11 204	11 196	11 862

Source: Table 25 of the 2006 annual review of the red meat industry by Agriculture and Agri-Food Canada (Agriculture and Agri-Food Canada 2007).

The traceability of Cattle in Canada

Animal identification has long be used in Canada to assist in the eradication contagious diseases. From the 1940s to the 1980s, animal identification was used to eradicate tuberculosis and brucellosis (Stanford et al. 2001). However, animal identification requirements were relaxed in 1985 following the successful eradication of contagious diseases in Canadian cattle (Souza-Monteiro and Caswell 2004). In 1985, approximately 95% of the herds in Canada were individually identified. In 1995, this number was down to less than 10% (Stanford et al. 2001).

Following the outbreaks of BSE in Europe in the 1990s, the Canadian cattle industry and the CFIA were concerned that the lack of animal identification could to lead the lost of export markets in the event of the discovery of diseases in Canadian cattle. The Canadian Cattle Identification Agency (CCIA) was created in 1998 with the stated goal of establishing national cattle identification. Since January 2001, with the amendments made to the Health of Animals Act, all cattle must be tagged with a CCIA-approved ear tag before leaving the herd of origin. Since July 2001, the abattoirs are required to read the tags and transfer the information to the CCIA. The identity of an animal is preserved until the carcass is inspected (Stanford et al. 2001). The regulation is fully enforced, with monetary penalties for non-compliance ranging from $ Can 500 to $ Can 4 000, since July 2002 (Canadian Cattle Identification Agency 2007).

Under the rules of the Canadian identification system, each animal is identified before leaving the herd of origin with an identification tag attached to one ear. Each tag has a unique identification number that is allocated by the CCIA national database. The name, telephone number, address and postal code of the producers are recorded in the database. In 2003, the CCIA began the transition from bar code tags to radio frequency identification (RFID) tags. RFID tags are mandatory since September 2006. Only the tags supplied by 5 manufacturers are approved by the CCIA. In addition to the animal identification, the CCIA also offers a voluntary age verification program.

In 2000, the province of Québec adopted its own traceability requirements for animals by passing the Animal Health Protection Act (AHPA). The regulation fully came into effect in July 2002 for bovine. The regulation applies to ovine since 2004 and to cervides since 2007. Traceability for pork is planned for Spring 2008. The stated goal of the system is to protect livestock's health and ensure the biosafety of food consumed by Quebecers. The system is managed by Agri-Tracabilité Québec.inc (ATQ), a not-for-profit organization subsidized by the Québec government(Agri-Traçabilité Québec 2008).

Under the AHPA, each facility has to be registered to the ATQ. The animals are identified by 2 two tags: one dangle tag and one RFID tag. The cost for a pair of tags supplied by the ATQ to the producers has varied between $ Can 2 and $ Can 3.

The tags approved by the ATQ are supplied by Allflex. These tags are also approved by the CCIA.

A bovine born on a Québec farm must be tagged in the 7 days following birth or before leaving the farm, whichever comes first. For a birth on the pasture, the cattle must be tagged within five months following birth or before leaving the farm. Farmers must notify the ATQ of the birth of an animal in the 45 days following birth or the day after leaving the farm of origin. The delay to notify the ATQ for an animal born on the pasture is 5 months. When notifying the ATQ of the birth of an animal, the farmers must transmit the following information: the ATQ producer's number, the name and the address of the animal owner, the tag number, the site number given by the ATQ, the date of birth, the sex, and the date the animal was tagged.

Animals imported to Québec must be tagged on arrival. The ATQ must be notified in 30 days following the arrival of an animal. Every time an animal is moved to an other facility, the ATQ must be notified. The facilities must transmit to the ATQ the number of the animal, the date of transfer, the vehicle license plate number and the registration numbers of the facilities. The tags can be removed only at the slaughterhouse by the operator. Therefore, all the movements of cattle is recorded from birth of the animal until its death. Work is currently underway to extend traceability up to consumers.

The difference between the CCIA and the ATQ systems is that cattle producers in Québec have implemented a traceability system while the rest of the Canadian producers have an identification system. The ATQ manages a system that follows all the movements of an animal from its birth until its death while the CCIA only identifies the origin of an animal.

BSE in Canada and in the United States

BSE is a fatal neurodegenerative disease of cattle. It is believed that the disease is caused by the presence of an abnormal protein called a prion. BSE occurs sporadically but can be transmitted through contaminated feed. The disease may also be transmitted from a cow to its calve. BSE has an incubation period of 4-5 years.

BSE took an epidemic proportion in England in the late 1980s. Protein supplements made of animal carcasses were identified as the disease vector and banished in 1988. It is estimated that 400 000 BSE infected cattle have entered the human food chain in England. BSE was first linked to the variant-Creutzfeldt-Jakob disease (vCJD) in 1996. It is estimated that about 160 people have died of vCJD in England (USDA Food Safety Research Information Office 2007).

BSE was first found in Canada in 1993 in a beef cow imported from England in 1987 (Canadian Food Inspection Agency 2008). The first domestic case of BSE in Canada was disclosed in May 2003. The animal was 6-8 years old cow in Alberta. As of April 2008, 12 cases of mad cow have been confirmed in Canada. In the United States, 3 cases have been confirmed with one of them linked to a cow imported from Canada. Table 4 shows the confirmed cases of BSE in North America.

When the first case of BSE was discovered in Canada in May 2003, the United States and several other countries immediately banned the imports of ruminants and ruminant products from Canada. In August 2003, the ban for selected cut of beef from animals under 30 months old was lifted by the United States and Mexico.

When BSE was discovered in the United States in December 2003. Canada restricted imports of cattle from the United States to animals under 20 months of age and to boneless beef cuts from cattle under 30 months of age. The imports of cattle and beef from Canada and United States are still restricted by many countries.[5] The

[5] For a timeline of the BSE crisis in Canada, see CBC News: http://www.cbc.ca/news/background/madcow/timeline.html.

Table 4. Confirmed cases of BSE in Canada and the United States

	Date	Location	Note
Canada			
	05/20/2003	Northern Alberta	6-8 years old cow
	01/02/2005	Northern Alberta	8 years old Holstein cow
	01/11/2005	Innisfail, Alberta	6 years old Charolais beef cow
	01/11/2006	North Central Alberta	5 years old Holstein-Hereford
	04/16/2006	Fraser Valley, B.C.	6 years old Holstein cow
	07/03/2006	Manitoba	16 or 17 years old Charolais cow
	07/13/2006	Northern Alberta	4 years old dairy cow
	08/23/2006	Northern Alberta	8-10 years old Charolais cow
	02/07/2007	Northern Alberta	7 years old Angus bull
	05/05/2007	Fraser Valley, B.C.	5 years old Holstein cow
	12/18/2007	Alberta	13 years old beef cow
	02/26/2007	Alberta	6 years old dairy cow
U.S.			
	12/23/2003	Washington State	The cow was imported from Alberta
	05/24/2005	Texas	The cow was first tested in Nov. 2004
	03/15/2006	Alabama	10 years old beef cow

Source: Canadian Food Inspection Agency (2008) and USDA/APHIS (2008).

Canadian cattle identification system did not prevent the ban of Canadian cattle and meat on the international market but it did help speed and lend confidence to the investigation that followed the discovery of the first case of BSE (Lawrence et al. 2003).

Federal and provincial governments in Canada instituted help programs to compensate producers for the decrease in the price of cattle caused by the BSE crisis. The Federal-Provincial Bovine Spongiform Encephalopathy Recovery Program implemented in June 2003 offered Canadian producers a compensation equal to the difference between a base price and an average weekly market price.[6] However, the program did not benefit producers as expected and provincial governments investi-

[6]See Le Roy, Klein, and Arbenser (2007) for an evaluation of the help programs offered to Canadian cattle producers.

gated the behavior of slaughterhouses and retailers during the BSE crisis (see e.g. Jacob, Doyon, and Librowicz 2003; Auditor General of Canada 2004).

The BSE crisis had significant effects on the Canadian cattle industry. Rude, Carlberg, and Pellow (2007) analyze how the rapid expansion of the slaughtering capacity in Canada induced by the ban of Canadian cattle in the United States affected the Canadian cattle and beef industry. The authors find that the price of feeder cattle would eventually almost recover to their pre-BSE level while the cull cattle prices would stay below their pre-BSE level. Other changes in the Canadian cattle industry induced by the BSE crisis include increased control over the quality of cattle and feed. For instance, the CFIA responded to the crisis by testing more cattle for BSE and increasing the restrictions on animal feed for ruminants (Le Roy, Klein, and Arbenser 2007). However, slaughterhouses must now segregate and dispose of cuts that have a higher risk of carrying the prion responsible for BSE.

Theoretical model

We develop a conceptual model to derive testable hypotheses on the effects of implementing cattle traceability in Québec. We model the demand and supply of cattle considering the relationship between farms and slaughterhouses. We do not specify functional forms when possible for more generality.

Beef is produced by slaughterhouses from two inputs: cattle and labor. Here, the labor variable is defined as an aggregate of all inputs, other than cattle, that enter into the production of beef. We simplify by ignoring different types of cuts of beef or by considering cattle of different quality. The quantity of beef produced is a function of the quantity of cattle from Québec slaughtered $\tilde{X}$, the quantity of cattle from another origin slaughtered $\tilde{Y}$ and the quantity of labor ℓ

$$(1) \quad Q = q(\tilde{X}, \tilde{Y}, \ell).$$

The cattle from another origin are any cattle that are not from Québec, e.g. cattle from Ontario, Alberta or the United States.

Traceability increases or decreases the marginal product of cattle depending on whether its net effect on slaughterhouses' productivity is positive or negative. We model the effect of traceability on slaughterhouses by considering a transaction cost per unit of cattle such that

(2) $\tilde{X} = f(T_X)X$

and

(3) $\tilde{Y} = f(T_Y)Y,$

where $f(T) \in (0,1)$ and where X is the quantity of Québec cattle bought by slaughterhouses and Y is the quantity of cattle from another origin bought by slaughterhouses. The function $f(T)$ is similar to the iceberg assumption used Paul A. Samuelson to model transportation costs (Samuelson 1952).[7] If more traceability is beneficial to the slaughterhouses, more traceability reduces transaction cost and $f(T)$ is an increasing function of the degree of traceability, $f_T > 0$ (the iceberg freezes). However, if more traceability does not benefit the slaughterhouses, traceability increases the transaction cost and $f(T)$ is a decreasing function of the degree of traceability $f_T < 0$ (the iceberg melts).

Slaughterhouses must invest in traceability technology and incur expenses to read tags and preserve the traceability of cattle. On the other side, increased traceability may induced farmers to deliver higher quality cattle (see for exemple Pouliot

[7] The iceberg assumption has also been used in the economics literature in a variety of topics such as product safety (Oi 1973) and smuggling (Pitt 1981).

and Sumner 2008). These benefits and costs of traceability are examples of transaction costs incorporated in the function $f(T)$.

Slaughterhouses are competitive firms that buy Québec cattle at a price W_X or cattle from another origin at a price W_Y. The price of labor is given by W_ℓ. The profit of a slaughterhouse is given by

$$(4) \quad \Pi_p = Pq(\tilde{X}, \tilde{Y}, \ell) - w_X X - w_Y Y - W_\ell \ell,$$

where P is the price of meat. Slaughterhouses maximize their profits by choosing the optimal quantity of Québec cattle, the optimal quantity of cattle from another origin and the optimal quantity of labor. The first order conditions for the maximization of profit by slaughterhouses give the inverse demand functions for cattle:

$$(5) \quad W_X = Pq_X f(T_X);$$

$$(6) \quad W_Y = Pq_Y f(T_Y);$$

and the inverse demand function for labor:

$$(7) \quad W_\ell = Pq_\ell.$$

Québec cattle and cattle from another origin that are processed, after the quantities of cattle are adjusted for transaction costs, are perfect substitute such that the marginal products of the two types of cattle are identical, $q_X = q_Y$.

The supply of Québec cattle is given by

$$(8) \quad X = g(W_X, T_X, \mathbf{b_X})$$

where $\mathbf{b_X}$ is a vector of exogenous variables and $g()$ is an increasing function for W_X. Like the effect of increased traceability on slaughterhouses' productivity, the net effects of increased traceability on farmers' productivity is either positive or negative. Therefore, augmented traceability either shifts the supply of cattle up, $g_T > 0$, or down, $g_T < 0$.

Figure 1 and the data in table 1 show that the Québec cattle industry is small compared to its Albertan and American counterparts. Thus, we consider that the Québec cattle industry is sufficiently small such that the price of cattle is exogenously given.[8] We simply let price of cattle from outside of Québec be

$$(9) \quad W_Y = h(T_Y, \mathbf{b_Y}),$$

where $\mathbf{b_Y}$ is a vector of exogenous variables that affect the supply of cattle in North America.

Remember that the labor variable in this model is a generic variable for inputs used by slaughterhouses other than cattle. For instance, storage in refrigerated facilities, sanitation equipments, and labor are inputs entering in the production of beef. The supply curve of labor is nondecreasing with respect to the quantity of labor, i.e. $W_\ell \geq 0$.

Our model allows us to compare the price of domestic cattle to the price of other cattle. Using (5) and (6) we find

$$(10) \quad W_X = \frac{f(T_X)}{f(T_Y)} W_Y.$$

That is, the price of Québec cattle is equalled to the ratio of the transaction cost for Québec cattle and cattle from another origin, $f(T_X)/f(T_Y)$, multiplied by the price of cattle from another origin, W_Y. We will refer to (10) as the price equation. Taking the

[8]We will not test empirically the exogeneity assumption in this version of the paper.

partial derivative of (10) with respect to the degree of traceability for Québec cattle we find

$$(11)\quad \frac{\partial W_X}{\partial T_X} = f_{T_X}\frac{W_Y}{f(T_Y)}.$$

That is, augmented traceability of Québec cattle increases the price of Québec cattle if traceability reduces the transaction cost of Québec cattle to the slaughterhouses, i.e. when $f_{T_X} > 0$. However, augmented traceability of Québec cattle decreases the price of Québec cattle when traceability increases the transaction cost of Québec cattle to the slaughterhouses, i.e. when $f_{T_X} > 0$.

Using (10) in (8), we can write that

$$(12)\quad X = g\left(\frac{f(T_X)}{f(T_Y)}W_Y, T_X, \mathbf{b_X}\right).$$

We will refer to (12) as the supply equation. The effect of increased traceability on the supply of Québec cattle is found by taking the partial derivative of (12) with respect to T_X

$$(13)\quad \frac{\partial X}{\partial T_X} = g_{W_X} f_{T_X}\frac{W_Y}{f(T_Y)} + g_T.$$

Increased traceability affects the supply of Québec cattle in two ways: 1) it changes the price received by farmers (movement along the supply curve) and 2) changes farmers' productivity (shifts the supply curve). The first term on the right-hand-side of (13), $g_{W_X} f_{T_X} W_Y / f(T_Y)$, is the movement along the supply curve caused by the change in the price of cattle from increased traceability. The second term on the right-hand-side of (13), g_T, is the shift in the supply curve due to the change in productivity of Québec farmers from increased traceability.

The shift of the supply curve can be either positive or negative. Traceability is costly to farmers. However, traceability provides benefits to farmers such as it reduces the cost of managing cattle herds and contributes to eradicate contagious cattle diseases rapidly. Thus, the net effect of increased traceability is positive if traceability provides significant benefits while the costs of traceability are small. However, the net effect of increased traceability is negative if the costs of implementing and maintaining traceability outweigh the benefits.

Future work

Our theoretical model shows that increased traceability in Québec has two effects: 1) increased traceability affects the price paid to cattle producers because it changes the transaction costs of slaughterhouses, and 2) increased traceability changes the productivity of farmers. These two effects can be measured by estimating the price equation in (10) and the supply equation in (12). Estimating expression (10) will allow us to measure the monetary gains (or costs) in terms of transaction cost to the slaughterhouses of increased traceability. Estimating expression (12) will allow us to measure the productivity gains (or losses) from increased traceability to farmers. To correctly estimate (10) and (12), we must account for a variety of factors.

First, we do not expect to observe an immediate shock on the price of Québec cattle following the implementation of the traceability system. Rather, we expect traceability to affect the supply and the processing of cattle smoothly. The cattle traceability regulation in Québec and the animal identification regulation for the rest of Canada were adopted in 2000. The implementation of the two regulations were phased out such that animals in Canada had to be identified as early as January 2001 but the regulation was not enforced before summer 2002. Cattle traceability in Québec and animal identification on the rest of Canada were fully enforced in summer 2002. Thus, compliance with the regulation should have increased from the moment of the announcement of the new regulation to reach a maximum and stabilize in summer 2002.

Second, traceability may not lead to immediate productivity gains for farmers and slaughterhouses. When traceability was first enforced in 2002, old animals were identified for the first time. The traceability of these animals was limited to the current farm. That is, all the movements of the animals prior to the implementation of the traceability system and the farm of origin were not recorded. Thus, productivity gains associated to better traceability were potentially low because the whole history of the animal was not recorded. Moreover, gains from better traceability may be experienced only when a hazard threatened the supply of cattle. For instance, gains from improved traceability may occur when cases of foot and mouth disease are discovered and the traceability system successfully contribute to control the outbreak. These gains from better disease control may lead to productivity gains that are only observed in the long term.

Third, the discovery of BSE in Canada in 2003 changed the cattle market in Canada. As discussed in the subsection on the discoveries of BSE in Canada and in the United States, Canadian cattle and beef were banned from most importing countries immediately after the first case of BSE was found in Alberta. The ban of Canadian cattle in the United States lasted over a year and restrictions are now imposed on the age of animals that can be exported.

We do not model or attempt to estimate the gradual changes in transaction cost and productivity from improved traceability and the effects of the BSE crisis. Rather, we will compare the period before the implementation of traceability, prior to 2001, to the most recent observations. This approach is similar to an event study.

Expression (12) can be specified empirically in its logarithmic as

$$(14) \quad w_{x,t} = \beta_0 + \Gamma\, Trac + \beta_w w_{y,t} + \beta_z \mathbf{Z_t} + \varepsilon_t,$$

where $w_{x,t}$ is the log of the price of cattle in Québec at time t, β_0 is the intercept, $Trac$ is dummy variable for traceability that takes the value one for the observations after the implementation of traceability and zero for the observations before traceability was adopted, $w_{y,t}$ is the log of the price of cattle from another origin, e.g. the price of cattle in Alberta, $\mathbf{Z}_t$ is a vector of covariates and ε_t is an error term. The coefficient Γ represents the premium for traceable Québec cattle. If the quality of cattle in Québec and in the other region did not change from factors other than traceability, the coefficient Γ can be interpreted as the added value due to Québec cattle from increased traceability. The variable $w_{y,t}$, if exogenous, controls for any shock that affects the price of cattle in Québec. The coefficient β_w can be interpreted as the degree of integration between the Québec cattle industry and the cattle from another origin.

Estimating a supply function for cattle has proved difficult and a voluminous literature is devoted to the subject (see for instance Jarvis 1974; Nerlove 1979; Foster and Burt 1992; Nerlove and Bessler 2001). The supply of cattle depends on the biological process proper to cattle and on price expected by farmers for cattle in the future. One possible approach is the "naive" expectations model where farmers form their expectations on the current price from the prices that were observed on the k previous periods. Thus, expression (12) can be empirically specified as an autoregressive lag model

$$(15)\quad x_t = \phi_0 + \rho\ Trac + d_t \sum_{i=0}^{k} \phi_{0,t-i} w_{y,t-i} + (1-d_t) \sum_{i=0}^{k} \phi_{1,t-i} w_{y,t-i} + \phi_z \mathbf{Z_t} + \upsilon_t,$$

where x_t is the log of the quantity of Québec cattle slaughtered, d_t is a dummy variable taking the value 0 before the implementation of traceability and a value of 1 after traceability has been implemented, and υ_t is an error term. The coefficient ρ is the shift in the supply curve of Québec cattle due to increased traceability. The coefficients $\phi_{0,i}$ represent the effects of a change in the log of the price at period $t-i$ on the log of the quantity at time t before the implementation of traceability. Analogously, the coefficients $\phi_{0,i}$ represent the effect of a change in the log of the price at period $t-i$ on the log of the quantity at time t before the implementation of traceability.

The long term elasticity before the implementation of traceability is given by $\sum_{i=0}^{k}\phi_{0,i}$ and the long term elasticity after the implementation of traceability is given by $\sum_{i=0}^{k}\phi_{1,i}$. Comparing these two measures of the price elasticity along with the value of ρ would give us the effect of increased traceability on cattle farmers as suggested by expression (13).

We can estimate the models in (14) and (15) using weekly data on the auctioned prices and quantities from Québec and other provinces in Canada, and by using similar data from the United States. However, the results from these estimations would be subject to some caveats. The structure of the Canadian cattle industry has changed since 2000. For instance, the type of animal slaughtered (black and red angus, holstein, cull cows), the age and the weight that animals slaughtered may have changed over the years. These changes cannot all be taken into account in the vector of control variables $\mathbf{Z}_t$ and may then appear in the traceability coefficients Γ and ρ, biasing our results.

An alternative approach would be to use disaggregated auction data that would allow us to add more control variable such as the characteristics of individual animals. Kellom et al. (2008) use auction data and find a premium for source and age verification of \$ 12.83 for a 272 kg calf sold for about \$ 700. That is, a 1.8 % premium is paid for origin and age verified cattle. We could use a similar approach subject to obtaining the data for Québec cattle and for cattle from other provinces.

Conclusion

Animal identification and animal traceability have lept to the front of the food policy agenda. The ongoing implementation of the National Animal Identification System in United States has raised concerns over the costs and benefits of implementing and maintaining such a system. In this paper, we lay the foundations for estimating the costs and benefits of implementing cattle traceability in Québec. Our results could eventually be used to estimate the costs and benefits of adopting a similar system in the United States.

We briefly describe the Canadian cattle and meat industry. The cattle and calves industry is the largest agricultural sector in Canada. The production of beef cattle is mainly located in Alberta while dairy production is concentrated in Ontario and Québec. The American and Canadian cattle industry were well integrated before the discovery of BSE in Canada in 2003.

The Canadian cattle industry has undergone major changes over the last decade. Notably, animal identification is mandatory and enforced since summer 2002. In Québec, animal identification was supplemented by the mandatory traceability of cattle.

We present a theoretical model of the effects of cattle traceability in Québec on slaughterhouses and farmers. Our model shows that the effects of traceability can be estimated from two equations. The price equation describes the costs or gains of increased traceability in terms of transaction to slaughterhouses. The supply equation shows how increased traceability affects the production of cattle in Québec.

We briefly describe our strategy to estimate the effects of mandatory cattle traceability in Québec. The estimation of the price equation may be facilitated by the exogeneity of the price of cattle due the small size of the Québec cattle industry.

Estimating the supply curve of Québec cattle may prove difficult as suggested by the voluminous empirical literature on supply.

Our work will provide new estimates of the effects of implementing and maintaining the traceability of cattle. One of our contribution will be to isolate the effects of increased traceability on farmers and slaughterhouses. We will use our estimate to simulate the effects of implementing a cattle traceability system similar to the Québec system in the rest of Canada and in the United States. This would be to our knowledge the first costs and benefits estimates of cattle traceability applied to the North American cattle industry.

References

Agri-Traçabilité Québec. 2008. Available online at: http://www.agri-tracabilite.qc.ca/en/index.html, Accessed on 04/11/08.

Agriculture and Agri-Food Canada. 2007. "Red Meat Market Information: Annual Livestock Market Review." Available online a: http://www.agr.gc.ca/redmeat/almrcalendar.htm, Accessed on 12/05/07.

Auditor General of Canada. 2004. "Report of the Auditor General on the Alberta Government's BSE related Assistance Programs." Available online at: http://www.oag.ab.ca/files/oag/OAG_BSE_2004.pdf.

Bailey, D., J. Robb, and L. Checketts. 2005. "Perspectives on Traceability and BSE Testing in the U.S. Beef Industry." *Choices* 20:293–297.

Canadian Cattle Identification Agency. 2007. "About CCIA." Available online at http://www.canadaid.com/about, Accessed on 12/07/07.

Canadian Food Inspection Agency. 2008. "Bovine Spongiform Encephalopathy (BSE) in North America." Available online at http://www.inspection.gc.ca/english/anima/heasan/disemala/bseesb/bseesbindexe.shtml, Accessed on 04/29/08.

Economic Research Service. 2008. "U.S. Beef and Cattle Industry: Background Statistics and Information." Available online at: http://www.ers.usda.gov/news/BSECoverage.htm, Accessed on 04/29/2008.

Foster, K.A., and O.R. Burt. 1992. "A Dynamic Model of Investment in the U.S. Cattle Industry." *Journal of Business & Economic Statistics* 10:419–426.

Jacob, G., M. Doyon, and M. Librowicz. 2003. "Rapport sur l'Évolution des Prix de la Viande Bovine Durant la Période du 20 Mai au 30 Août 2003." Working paper, Ministère de lŠAgriculture, des Pêcheries et de l'Alimentation.

Jarvis, L.S. 1974. "Cattle as Capital Goods and Ranchers as Portfolio Managers: An Application to the Argentine Cattle Sector." *The Journal of Political Economy*

82:489–520.

Kellom, A., J. Paterson, J. Vanek, M. Watts, and M. Harbac. 2008. "The Effects of Afge and Source Verification of Calves on Value Received on Superior Livestock Video Auctions." *Proceedings, Western Section, American Society of Animal Science* 59.

Lawrence, J.D., D. Strohbehn, D. Loy, and R. Clause. 2003. "Lessons Learned from the Canadian Cattle Industry: National Animal Identification and The Mad Cow." Research Paper No. 03-MRP 7, MATRIC, Iowa State University, Ames, Iowa 50011-1070.

Le Roy, D.G., K.K. Klein, and L.N. Arbenser. 2007. "An Evaluation of Economic Models to Provide Policy Advice in Response to the BSE Crisis in Canada." *Canadian Journal of Agricultural Economics* 55:551–564.

Nerlove, M. 1979. "The Dynamics of Supply: Retrospect and Prospect." *American Journal of Agricultural Economics* 61:874–888.

Nerlove, M., and D.A. Bessler. 2001. "Expectations, Information and Dynamics." In B. G. Gardner and G. Rausser, eds. *Handbook of Agricultural Economics*. Elsevier Science B.V., vol. 1, chap. 3, pp. 155–206.

Oi, W.Y. 1973. "The Economics of Product Safety." *The Bell Journal of Economics and Management Science* 4:3–28.

Pitt, M.M. 1981. "Smuggling and Price Disparity." *Journal of International Economics* 11:447–458.

Pouliot, S., and D.A. Sumner. 2008. "Traceability, Liability and Incentives for Food Safety and Quality." *American Journal of Agricultural Economics* 90:15–27.

Rude, J., J. Carlberg, and S. Pellow. 2007. "Intergation to Fragmentation: Post-BSE Canadian Cattle Markets, Processing Capacity, and Cattle Prices." *Canadian Journal of Agricultural Economics* 55:197–216.

Samuelson, P.A. 1952. "The Transfer Problem and Transport Costs." *Economic Journal* 62:278–304.

Souza-Monteiro, D.M., and J. Caswell. 2004. "The Economics of Implementing Traceability in Beef Supply Chains: trends in Major Producing and Trading Countries." Working Paper No. 2004-6, University of Massachussetts Amherst, Department or Resource Economics.

Stanford, K., J. Stitt, J. Kellar, and T. McAllister. 2001. "Traceability in Cattle and Small Ruminant in Canada." *Revue Scientifique et Technique de l'Office International des Épizooties* 20:510–522.

Statisitics Canada. 2008. "Farm Cash Receipts." Available online at: http://www40.statcan.ca/l01/cst01/agri03a.htm, Accessed on 04/29/2008.

Statistics Canada. 2007. "Livestock and Aquaculture." Available online at: http://www40.statcan.ca/l01/cst01/prim50a.htm, Accessed on 12/05/07.

Thompson, A.H. 2008. "Gencor becomes latest beef industry casualty." AgriSuccess Express. Available online at http://www.fcc-fac.ca/newsletters/en/express/articles/20080411_e.asp, Accessed on 04/29/2008.

USDA Food Safety Research Information Office. 2007. "A Focus on Bovine Spongiform Encephalopathy." Available online at: http://fsrio.nal.usda.gov/document_fsheet.php?product_id=169, Accessed on 12/10/07.

USDA/APHID. 2008. "National Animal Identification System." Available at http://animalid.aphis.usda.gov/nais/index.shtml, Accessed on 04/11/08.

USDA/APHIS. 2008. "Newsroom: BSE in the United States." Available online at: http://www.aphis.usda.gov/newsroom/hot_issues/bse/bse_in_usa.shtml, Accessed on 04/29/08.

Vollrath, T., and C. Hallahan. 2006. "Testing the Integration of U.S.-Canadian Meat and Livestock Markets." *Canadian Journal of Agricultural Economics* 54:55–79.