Background Paper

for

Reorienting our food systems for greater sustainability: potential policies and strategies [*]

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High-level summary

Issues that are significant within a food system approach but are beyond the scope of our work and discussion are indicated by ⋆.

- Canadian agriculture is loosing farmers, due to escalating costs of small-scale farming, and with that possibly a wealth of experience and locally-relevant knowledge of farming. This is a well-recognized risk factor.

- Canadian agricultural production is increasingly concentrated. To the extent that this trend reinforces monoculture farming and reduces biodiversity (both on and off the farm), the implications for economic diversification, agricultural vulnerability, and food security are substantial, posing significant risks to both producers and consumers. With a larger allowance for systemic risk, in the long term, these trends may increase Canada's reliance on imported food, another risk factor.

⋆ Concentration of production has strong implications for on and off-farm employment, farm wages, farm incomes, affordability of food, and rural communities, as well as how incomes are distributed. We are mindful that a more comprehensive systems approach would need to grapple with these socio-economic risks and health implications, which increasingly require prioritization.

- Within agriculture, crop production, on average, has proven to be an economically more viable sector. While animal agriculture is as concentrated as crop agriculture (in fact even more), large animal operators are not necessarily more profitable than their small and medium-size counterparts. This suggests that there are "natural" limits to economies of scale in animal agriculture and reducing the relative and absolute size of this sector can present novel economic opportunities.

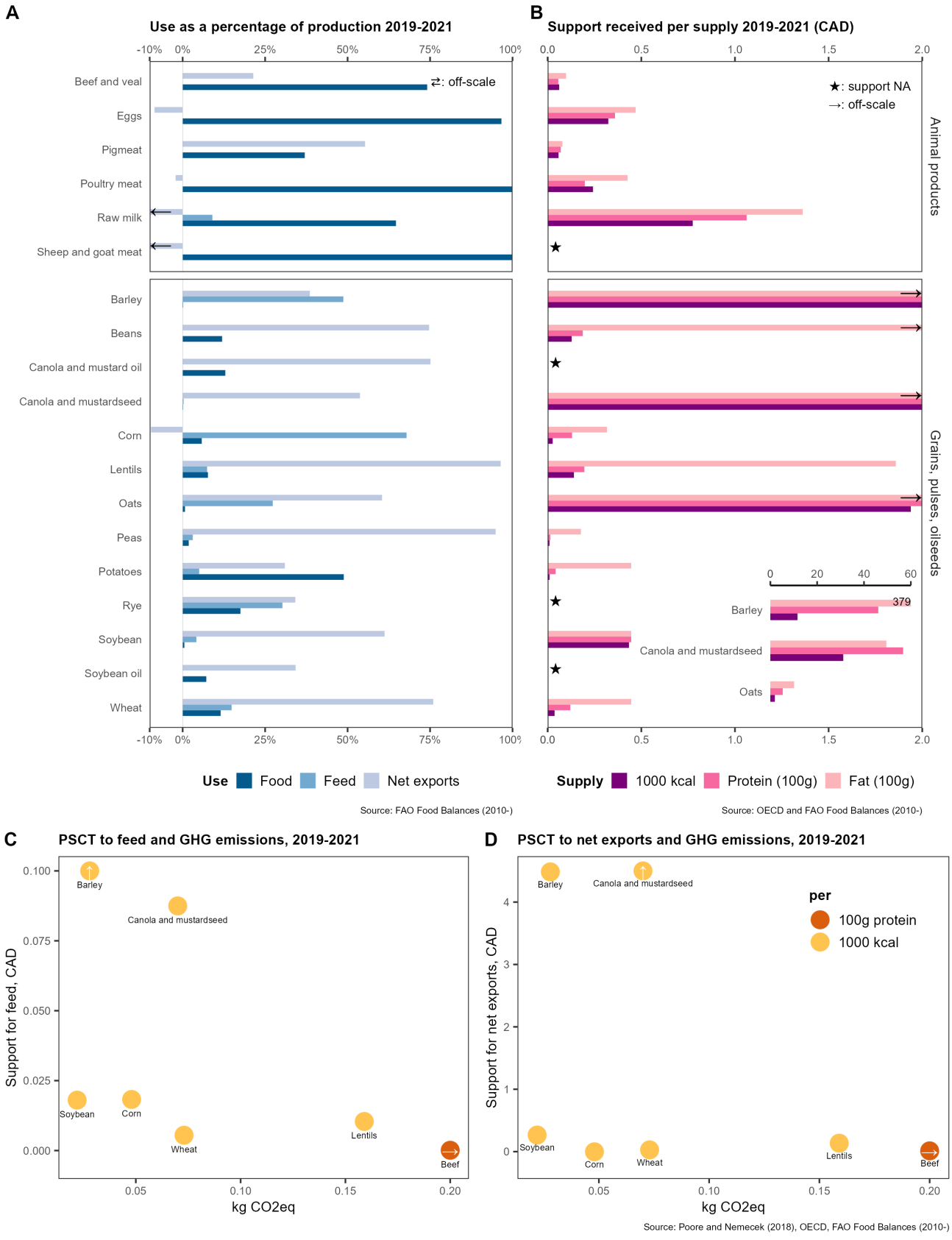
- Agricultural producer support, particularly direct budgetary transfers as a percentage of Canadian gross domestic product (GDP), has declined over time, and there has been a strong shift toward program payments, which are designed to serve as an income safety net for farmers, and not as direct subsidies. These payments alone constitute a significant percentage of net farm income.

- While animal agriculture, especially egg, poultry and dairy milk producers are the biggest beneficiaries of transfers to producers from consumers through supply management, farm operators specializing in crop agriculture are the biggest direct recipients of program payments.

- Crop agriculture feeds humans. But most domestic crop production is diverted to industrial uses (like biodiesel), to animal agriculture as feed, and exported. Agricultural producer support policies therefore do not seem to directly support the diet of an average Canadian, let alone a diet that is recommended by 2019 Canada's Food Guide.

Figure A: Executive Summary in One Figure

In Canada, agricultural production support often benefits export oriented commodities and feed processing with corresponding GHG emissions



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1 Introduction

Canadian farmers and agricultural policies have over the years established a food system that is reliable and perceived to be safe by the average consumer. However, due to pressing domestic and global challenges outlined in our presentation, attention must now turn to environmental impact, healthy diets, and long-term risks. Collectively, risks to our natural environment, human health and global trading system raise questions about the sustainability of the current food systems. Scientific evidence shows that Canada has transgressed its national share of six planetary boundaries (Fanning et al., 2022).[1] Investments in agricultural production have an opportunity cost and these investments should complement, and should not compete with, necessary investments in the environment and healthy diets, which can no longer be deferred. Global risks have been amplifying over time. International trade in agricultural goods has always been a contested issue. Recent disruptions in global agricultural markets have further shown that it is naive to assume that international trade delivers a reliable "insurance" against systemic risks faced by Canadian producers and consumers of food. There are economic (employment and income), opportunity cost (when other areas receive less government support), and equity (distribution of income among Canadian farmers and those employed in the farm sector) considerations that inevitably position environmental sustainability, healthy diets, and the risks faced by Canadian agriculture within a food systems approach.

Our project examines a slice of Canada's food systems, albeit an important one: policies that support agricultural production. Existing policies were put in place for reasons that seemed appropriate at the time and they evolved over time. However, the risks we identify, consistent with the growing scientific consensus, strongly indicate that government supports and priorities and how industrial agriculture are practiced must change, and do so with urgency. This urgency is the driving force behind our project.

For real change to happen, policies, and frameworks or mental models upon which they are built must be ready to change as well. We think there are real opportunities that need to be explored. How might we rethink, reorient, and redesign Canada's agricultural production policies to address existing and emerging health, environmental, and global risks and opportunities?

To engage in a productive discussion about reorienting our food systems for greater sustainability, and one that is also aligned with Canada's Food Guide (Health Canada, 2019), we need a common understanding of the structure of the Canadian agricultural production, how it changed over time, and how the support for agricultural production shaped that structure.[2] Establishing this common background based on the best evidence is the driving force behind this background document.

[1] Planetary boundaries were introduced by Steffen et al. (2015).

[2] While domestic production does not necessarily shape the average Canadian diet, the gap between the average diet and 2019 Canada's Food Guide raises important questions.

2 Structural change in Canadian agriculture

In Canada structural transformation of agriculture has been an ongoing process for decades with stark implications for our food systems. A standard measure of structural transformation (or change) has been the changes over time in the number of persons employed in a sector (Syrquin, 1988; Dennis and İşcan, 2009; Briones and Felipe, 2013). In agriculture, the historical pattern has been a declining share of employment in agriculture and shrinking size of employment in the sector (Timmer, 1988; Timmer et al., 2015). Between 2011 and 2021, Canadian agriculture lost over 15 thousand farms, more than 1000 farms per year (Figure 1E).[3]

The shrinking number of farmers is "graying" the Canadian agriculture. According to Qualman and the National Farmers Union (2019), one-third of families left farming "in just the past generation. Worse still, young farmers—those under the age of 35—are being forced out at twice the rate of farmers overall; Canada has lost more than two-thirds of its young farmers since 1991." This exodus by young farmers from agriculture has profound implications for the size distribution of farms, as small to medium size farms are consolidated by large farms and young farmers find access to farmland prohibitively expensive.

Farm "size" can be measured using a monetary flow concept, like income, receipts or revenues, or by area, whereby farms are classified according to their size within a range, with the number of farms within a size classification that can be tracked over time. Monetary flows are useful because they represent a broad set of resources that are available to farmers that operate in a monetary economy. However, monetary flows change over time with changes in the general price level, making comparisons over time difficult, unless, of course, constant price data are used. Farm size classifications based on farmland do not have this complication, but farmland is not the most important factor for certain agricultural enterprises, such as poultry and greenhouse production.[4] Below we use both types of classifications to ensure that our conclusions about the size distribution of farms are robust to either monetary flows or agricultural land.

The most informative historical data available to us reports, in 2015 constant dollars, nine revenue classes, ranging from "less than $ 10,000", which we drop as it corresponds to a wide range of circumstances, to farms with revenues "$ 2,000,000 or over" (Figure 1A). From 1981 to 2016, the distribution of farms by gross farm receipt class changed considerably, with a significant decline in the number of farms with annual farm receipts of $ 250,000 or less and an increase in the number of farms with annual receipts above $ 500,000. While the divisions between small, medium and large farms based on receipt classes is admittedly imperfect, the classification provides a relatively long time perspective—and in constant dollars, which is not always available. In 2016, of all the farms with receipts $ 10,000 or more, less than 3 percent had receipts that were $ 2,000,000 or over: these large, high receipt farms constituted a small minority.

[3] To appreciate what this declining number of farmers might mean, and without passing any value judgement about specific occupations, we compared the farm employment with the number of legal professionals, a venerable and well-defined occupation. At this pace, Canada would have less farmers and more legal professionals by 2025.

[4] Statistics Canada defines farmland inclusive of cropland, land left fallow, pasture, woodland, wetland, and all other land used for farming purposes.

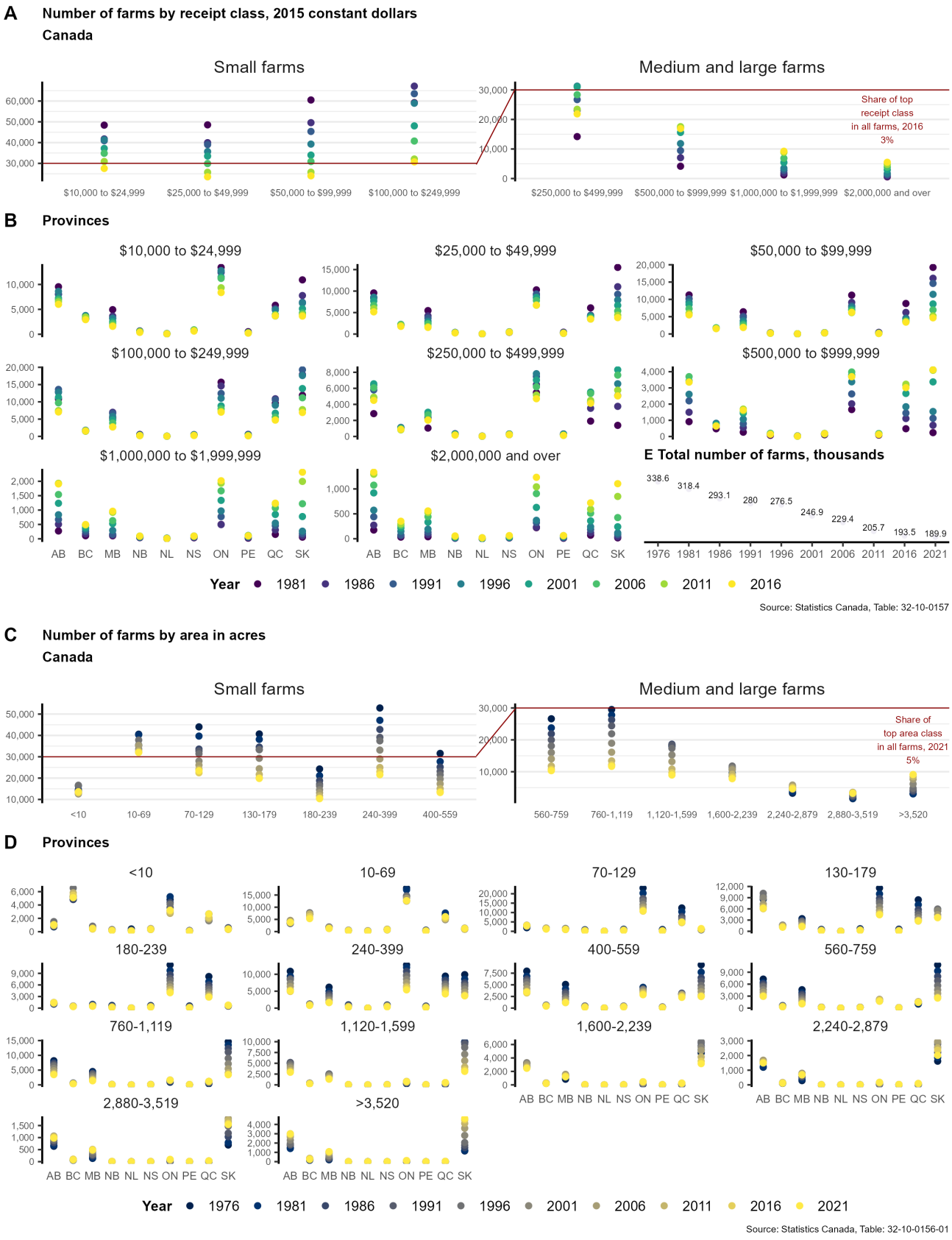

Figure 1: Number of farms by receipt class and area

The size distribution of farms by area available reports 14 distinct area classes, ranging from "Under 10.00 acres" to "3,520.00 acres and over" (Figure 1C). Classifying farms as small, medium, and large by area is imperfect, and does not account for agro-climatic considerations.[5] Despite its limitations, the data reveal the often-heard commentary that small- and medium-size farms have been shrinking in numbers: Since 1976, the number of farms in size categories with less than 1600 acres decreased significantly, with a noticeable increase in the number of large farms with more than 2240 acres. By 2021, the land consolidation has resulted in the largest area class farms with "3,520.00 acres and over" accounting for about 5% of all farms in Canada.

Provincially disaggregated data on the number of farms by receipt class (Figure 1B) and by area (Figure 1D) are consistent with the national trends. However, there are significant differences across these two distinct measures of farm size. In the case of receipts, national trends are pretty consistent across all the provinces, whereby there is a noticeable decline in the number of small and medium size farms by receipt class, and an increase in the number of large farms. In the case of area in acres, however, there are significant differences across provinces, likely associated with regional specialization in commodities like field crops versus horticulture. In Alberta, Manitoba, and Saskatchewan the consolidation of farms over time is striking. Ontario has seen a sharp decrease in the number of small and medium size farms, but not a corresponding increase in large farms. Quebec appears to be less affected by farm consolidation. Regardless of these provincial differences and differences between farm size measured by receipts and area, average farm in Canada is getting bigger. This escalation of size has certainly contributed to the graying of farming in Canada, as young farmers with little to no initial capital will find it prohibitively expensive to enter or will be expected to lease farmland, increasingly owned by private equity or large pension funds.[6]

Using publicly available data, it is possible to disaggregate the data on the number of farms by commodity. For animal agriculture, here we present the data for beef cows, dairy cows, hens and chickens, pigs, and sheep (Figure 2A–C). For crops, we present the data for wheat, corn for grain, corn for silage, barley, canola (rapeseed), and soybeans (Figure 2D–F). Since 1976, the number of farms reporting livestock and crops have uniformly decreased, soybeans, partly canola, and to some extent corn for grain being the exceptions. These three commodities have significant industrial uses and are also diverted into animal feed.

While the number of farms reporting livestock and poultry (turkey are not included) has declined across all primary animals, the average number of livestock and poultry per farm increased sharply since 1976 (Figure 2B–C). Consolidation in the livestock industry has been uniform across all provinces,

[5] In the Prairie provinces, for example, it is unlikely that a contemporary farm less than 5000 acres would be considered large—a category that is higher than the lower bound for *largest* area class in Statistics Canada's reporting system.

[6] European Parliament resolution of 27 April 2017 on the state of play of farmland concentration in the EU (2016/2141(INI)), for example, echoes an earlier wake up call by the European Economic and Social Committee of 21 January 2015 on land grabbing and states that "in 2013, in the 27-member EU, only 3.1 % of farms controlled 52.2 % of farmland in Europe; whereas, by contrast, 76.2 % of farms had the use of only 11.2 % of the agricultural land" concluding that "this trend runs counter to the European sustainable, multifunctional agricultural model". Unfortunately, Statistics Canada does not make data on holdings (cropland or farmland) by size as a percentage of total holdings. As a result, we are unable to report similar statistics for Canada. Financialisation of agricultural production, and corporate influence has implications for healthy and sustainable diets, and the environment (Stephens et al., 2022; GRAIN, 2024).

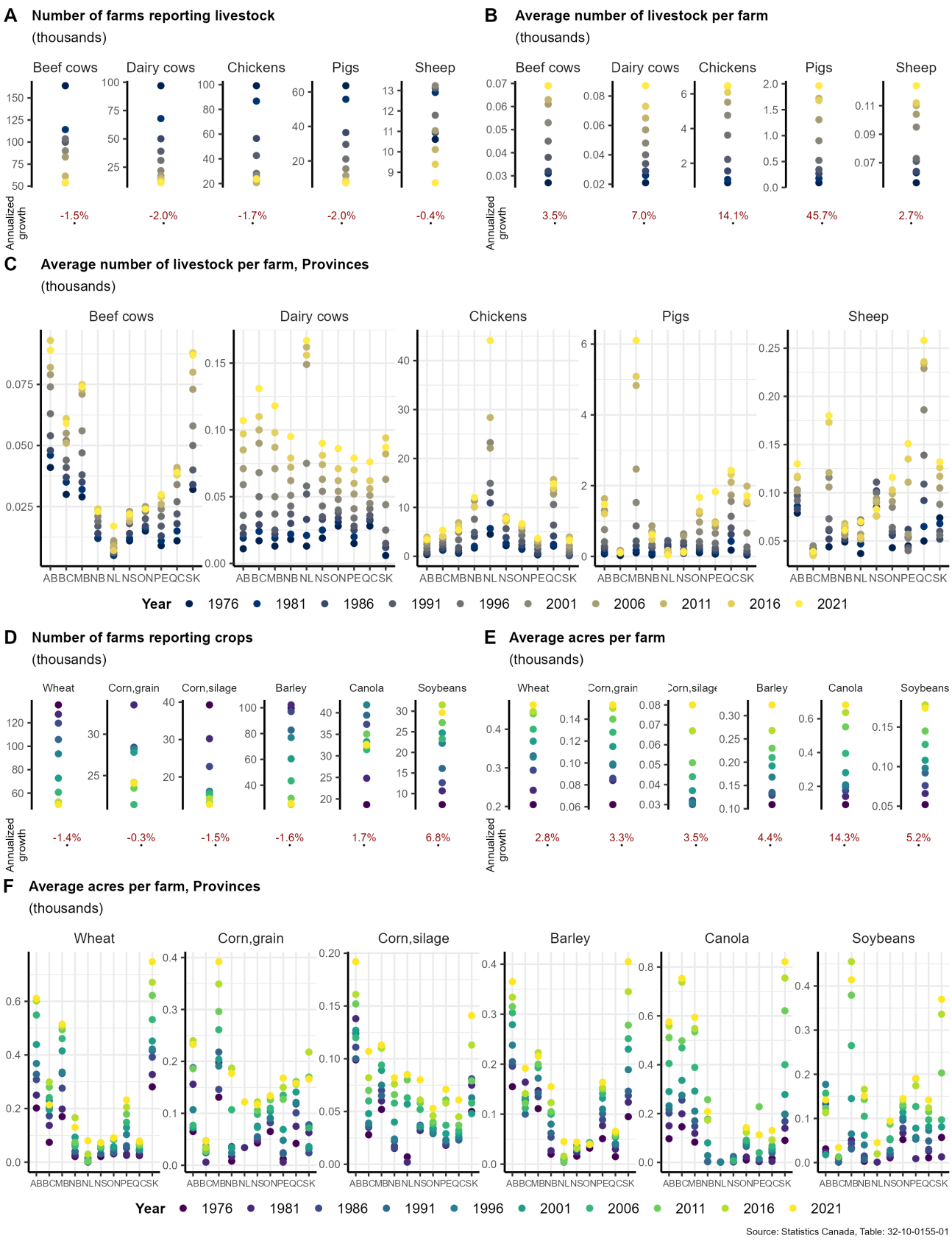

Figure 2: Number and average size of farms reporting livestock and crops

especially for beef cows where Alberta and Saskatchewan have seen particularly strong growth in average number of cows per farm. For farms reporting crops, the average acres per farm increased uniformly (Figure **??**E–F). The changes in average acres per farm over time are most prominent for commodities that are diverted to ethanol production (corn for grain) and oilseeds that are diverted to animal feed (canola and soybeans). Among the 10 Provinces, Manitoba has seen the most significant increases in average acres per farm reporting corn for grain, canola, and soybeans. Alberta and Saskatchewan have also seen substantial increases in average farm size in acres, with corresponding declines in the number of mid-size farms in these provinces.

3 Supply and disposition

3.1 Production

Does fewer farms mean less food for humans, feed for animals, and raw materials for industrial use produced in Canada? While the number of farms in Canada has been declining at a steady pace, and the consolidation of the farms has been ongoing, agricultural production continues to increase. A few animals dominate livestock agriculture— beef cows, dairy cows, hens and chickens, pigs, and sheep (Figure 3A). There are differences in the changes in the number of animals, and not all livestock numbers increased over time. The fluctuations in the number of beef cows are particularly noticeable. The Bovine spongiform encephalopathy (BSE or the "mad cow" disease) crisis of 2003-2005 in part accounts for the significant decline in the number of beef cows and it can be argued that the beef cow sector has not completely recovered from it since – although the number of beef cows remain higher than they were in the mid-1980s.

The number of dairy cows, by contrast, has seen a steady decline. However, milk production per cow has also been increasing and at a faster rate than the number of dairy cows. As a result, total milk production in Canada has been increasingly steadily. Time will tell whether and how the Canada–United States–Mexico Agreement will affect domestic dairy cow numbers and total milk production in Canada.

Commercial production of field crops (Figure 3B–C) is considerably more diverse, though several major crops dominate the sector. Within field crop production, beans (dry), corn for silage, lentils, peas, and oilseeds (canola and soybeans) have seen substantial growth since 1976, and production of grains (barley, oats, rye, and wheat) and flaxseed either remained stable or even declined. Changes in average yield per field crop is not the only explanation behind these production numbers. Barley production in Canada is half of what it was in the mid-1970s, despite a non-negligible 10% increase in average yields. Wheat (including durum wheat) production has recently been similar to what it was in 1976, although average yields have been about 30% higher than those in the 1970s. By contrast, while the production of lentils has increased more than fivefold since the mid-1970s, yields have lately been similar to what they were at that time. No doubt, shifts in demand are a critical driver of production values.[7]

[7]Throughout the text we use canola and rapeseed interchangeably. Statistics Canada lists canola and OECD and

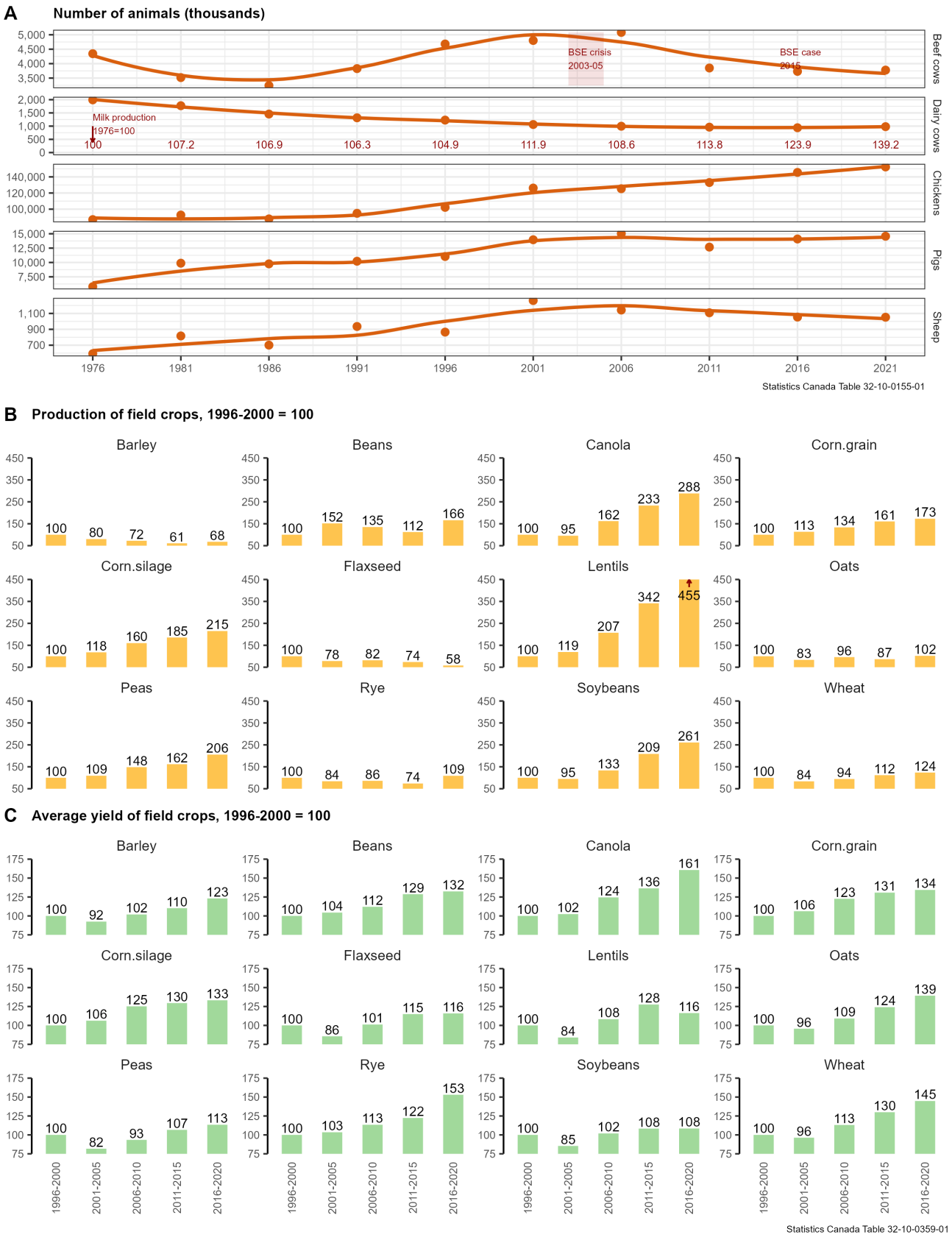

Figure 3: Farm production and yields

While providing a thorough demand analysis is beyond the scope of this background paper, it is instructive to explore two areas which provide insights on this issue: changes in the consumption of these food items over time (in per person terms) and changes in their disposition, or final demand use.

3.2 Consumption and disposition

The per capita consumption of meat, meat products and dairy milk is difficult to estimate because estimates of loss in handling and waste are difficult and varied depending on the source. Existing data suggests that relative to the 1976–1980 average, in Canada, while per capita poultry and sheep meat consumption have increased over time, the consumption of beef (bovine meat), milk and pigmeat have declined, with beef seeing the biggest decline, with 2016–2020 average standing at 59 percent of the 1976–1980 average (Figure 4A). Per capita consumption of beef, poultry, and milk has been below that of the United States since the early 1960s. For these three products, per capita consumption in Canada relative to that of the United States has declined the most for milk.

In Canada, dairy milk and chickens and hens are subject to a supply management, where producers require a quota license to do so. As we will discuss more below, one of the economic side effects of a supply management is that they tend to increase domestic prices above the border price, in this case primarily the unit price for the same commodity observed in the United States. A higher unit price would tend to discourage consumption as consumers substitute away from relatively higher unit priced goods and cannot afford to consume as much. It is difficult to say how much of an impact the supply managed systems have impacted consumption of milk and poultry in Canada. Judging from the relative per capital consumption of beef, which not only has been less than parity with the per capita consumption in the United States, but has been declining over the last six decades, it appears that supply management is at best a small contributor to the Canada–U.S. differences. The only commodity which might have been significantly affected by supply management is poultry. However, even in the case of poultry, the gap between the Canada–U.S. difference started to widen before the introduction of the National Chicken Marketing Agency. Moreover, since the early 2000s the gap has remained relatively constant, suggesting that consumer and food industry choices have had significantly more impact on the observed per capita consumption patterns than the supply management systems. None of this is meant to imply that supply managed systems have no impact on outcomes. It is just that costs of the system on consumers are difficult to assess and the benefits to producers are easy to identify. We will return to this point below.

The disposition of domestically produced field crops include seed, human food, industrial use, feed, dockage, exports, and waste. Such a detailed disposition requires many assumptions leading to many sources of uncertainty. It is difficult to have a standard definition of what constitutes "industrial use". As a result, the allocation of dispositions to industrial use is done on a case by case basis. According to AAFC (email communication by Lina Gordon dated April 16, 2024) for oilseeds, industrial use

FAO lists rapeseed. Technically, canola is a group of genetically modified cultivars of rapeseed (*Brassica napus*) with a relatively lower erucic acid content, primarily cultivated to produce cooking oil. Erucic acid, a monounsaturated fatty acid, has been implicated in Toxic Oil Syndrome and other health risks, but its toxicity for humans is debated (Galanty et al., 2023).

Figure 4: Consumption and disposition of animal products and crops

refers to the amount of product known to be used solely for industrial purposes: a historic variety of rapeseed is used to produce a specialty high-temperature resistant lubricant, and canola oil is used to produce biodiesel. For corn and wheat, industrial use refers to the portion of production diverted to produce ethanol for blending into gasoline. Canola, corn, and wheat are all used as human food as well, like canola oil used for cooking oil and wheat milled to produce flour is also considered food.

There are substantial statistical uncertainties surrounding the share of agricultural production that is disposed as feed. Unfortunately, Statistics Canada does not have separate estimates for animal feed, waste, and dockage—three very distinct categories of disposition, and this single category also includes estimation errors (Box 1). Moreover, for a number of grains, there are no separate estimates of human food and industrial uses, or estimates of human use have remained constant over time. In the case of flaxseed, even aggregated data on human food and industrial use are unavailable due to data confidentiality, meaning that domestic use data are grossly understated, comprising only the estimates of seed, loss in handling, feed, waste, dockage, and statistical discrepancy.

According to the Animal Nutrition Association of Canada, in 2022 an estimated 29.2 million (metric) tonnes (t)[8] of feed processed by commercial and on-site farm mills were consumed by Canadian livestock.Pigs (swine), beef and dairy cattle, poultry (layers, broilers, and turkey) accounted for about 97% of that total. While the share of feed in total cost of livestock production varies across species, this share is estimated to be as high as 75% (Animal Nutrition Association of Canada, 2021).

Grains and oilseeds make up the most significant inputs into the animal feed industry: predominantly corn as animal feed grain and soybean as animal feed protein. In the United States, corn accounts for 95 percent of total feed grain use, with sorghum, barley, and oats making up the remaining major feed grains (Economic Research Services, 2023). According Gary Berg of the United Soybean Board "animal agriculture consumes 97 percent of U.S. soybean meal" (mostly for chickens, hens and pigs) and "investing in animal agriculture helps grow demand for U.S. soybean farmers" (Smith, 2023).[9] Together with some minor mixed grains and non-traditional feed grains like millet and sorghum, these feed grains are the most significant inputs into the animal feed industry.

We use two separate sources to highlight the significance of animal feed as a source of demand for field crops. Statistics Canada, whose methods we discussed above, and FAO Food Balances, which is an internationally comparable data source on uses and dispositions of many food items. Statistics Canada publishes a combined value for feed, waste, dockage. FAO has separate internal estimates of feed. We report these feed estimates as a share of domestic supply (and use) and production (Figure 4C-D).[10] These commodities are internationally traded and for most of these commodities Canada is a net exporter of the commodity—in some cases a substantial exporter, demonstrated by

[8]Unfortunately, we do not have a breakdown of feedstocks to compare with the production data. Table S.1 lists our conversion factors and abbreviations.

[9]Soybean meal is a protein-rich byproduct of soybean crushing for oil extraction. Aside from being consumed as animal feed, soybean meal is also used as human food in tofu, soy milk, and meat substitutes, and has industrial uses like adhesives, biodegradable plastics, and biofuels (Agrilinkage, 2023). In the United States, 47 percent of domestic soybean supply was crushed, 45 percent was exported, and out of the total domestic disposition 42 percent was for biofuel production (USDA, 2024). Soybean disposition in Canada is also dominated by animal feed and exports (see below).

[10]Here domestic use includes "loss in handling" so that domestic supply equals domestic use, at least in principle.

Box 1 Feed, waste, and dockage: a technical note**.**

Accounting for dispositions as feed, waste, and dockage is remarkably difficult. In Canada, these dispositions publicly reported as a single item include a residual or an error term. The reason is that this item is based on the following accounting identity:

$$\mathsf{Supply}_t = \mathsf{Use}_t.$$

The above expression holds if independent estimates of supply and use were exactly equal to each other, which is never the case in practice. Due to these statistical discrepancies, it is best to express this relationship as

$$\mathsf{Supply}_t = \mathsf{Use}_t + \mathsf{Statistical\ discrepany}_t. \tag{1}$$

Supply over a period t consists of

$$\begin{gathered}\mathsf{Supply}_t := \mathsf{Domestic\ production}_t + \mathsf{Imports}_t - \Delta\mathsf{Stocks}_t \\ Y_t + M_t - \Delta S_t\end{gathered}$$

where $\Delta S_t := S_t - S_{t-1}$ corresponds to a change in stocks. Use_t consists of

$$\begin{gathered}\mathsf{Use}_t := \underbrace{\mathsf{Domestic\ use}_t}_{\text{food, industrial, seed, loss, fwd}} + \mathsf{Exports}_t \\ C_t + X_t.\end{gathered}$$

In the above expression fwd stands for Feed, Waste and Dockage. AAFC calculates fwd as the difference between Supply and the other components of Use

$$\underbrace{Y_t + M_t - \Delta S_t}_{\mathsf{Supply}} - (\mathsf{Food} + \mathsf{Industrial} + \mathsf{Seed} + \mathsf{Loss})_t - X_t = \underbrace{\mathsf{fwd}_t + \mathsf{Statistical\ discrepany}_t}_{\text{“Feed, Waste, Dockage”}}$$

Thus, what the AAFC publications report as “Feed, Waste, Dockage” include statistical discrepancy. Since this discrepancy can be large and can be either negative or positive, it is not unusual to find a negative number reported for Feed, Waste, Dockage. According to expert opinion (email communication by Lina Gordon dated April 16, 2024), a negative number usually indicates an error in production estimate, in part because production estimates are based on Statistic Canada surveys, which are subject to estimation error. On-farm consumption or intra-provincial transfers of grains are also missing. In the case of grain exports to the United States, the data are based on the grain shipped to the United States by licensed companies, but those shipped by unlicensed grain dealers or exported by container are not always accounted for. All such factors contribute the size and direction of the statistical discrepancy. In general, reports by Statistics Canada acknowledge the pervasiveness of “data gaps and the fragmentation of information on food supply chains” (Toor and Hamit-Haggar, 2021).

the large differences between ratios using domestic use and production values: when the ratio of feed to domestic use is more than the ratio of feed to production, Canada is a net exporter of the commodity in question. The commodity in which Canada imports more than it exports is corn, but the difference is minor and over the 2019–2021 period, exports net of imports has been on average less than 10 percent of the total Canadian production in volume (Figure 4E).

Unfortunately, the data are not always consistent across sources. While we would expect ratios based on Statistics Canada's feed, waste, dockage to be uniformly higher than those based on FAO's feed alone, this is not the case for corn from 2010 to 2019. Nevertheless, the estimates indicate that more than 70 percent of domestic supply of barley and oats, more than 50 percent of corn (and rye, although FAO data are contradictory), about 40 percent of pulses and wheat, and slightly more than 10 percent of peas are diverted to animal feed. So, grains and corn can be said to mostly feed animals.

For oilseeds, human food is not a significant disposition of domestic production either. For canola and soybeans, Statistics Canada reports no human food, with essentially all domestic use being diverted to industrial use. According to SoyCanada.ca in 2023 out of the 1.76 million metric tonnes (mt) of soybeans processed domestically about 78 percent (1.37 mt) was processed as meal or animal protein feed, and 19 percent (330,000 t) was processed for oil. Total domestic production in 2023 was 6.98 mt, out of which 4.4 mt (or about 63 percent of total production) was exported.[11] According to the Canadian Oilseed Processors Association, in 2023, out of a total 8.77 mt of canola processed domestically about 60 percent (5.22 mt) was processed for meal and 42 percent (3.65 mt) was processed for oil.[12]

Therefore, grains and oilseeds produced in Canada are essentially disposed as exports or for industrial use and animal feed. We cannot trace what happens to Canadian exports of canola or soybeans. Assuming, as Nye and Youngman (2024) we think plausibly do, that the composition of domestic disposition of these crops is representative of the international patterns, then we have to accept the conclusion that Canadian grain and oilseeds industries are only indirect sources of human food, and largely feed ruminant, pig, and chicken as farm animals in Canada and elsewhere.[13]

Crop agriculture in Canada is highly export oriented, the domestic production of pea and pulse production is almost entirely directed to export markets (Figure 4E). Beans, oats, wheat, canola and soybeans, as well as oils derived from these oilseeds are also highly export oriented (about 65 to 75 percent of all domestic production). Among animal products, while Canada has a trade surplus in beef and veal, and pigmeat, Canada imports more eggs, poultry meat, raw milk, and sheep and goat meat than is exported. Canada's substantial export surpluses in crop and animal agricultural products,

[11] Loss in handling, dockage and waste account for the remaining 3 percent of total production. About 24 percent of total meal produced and 42 percent of total oil produced were exported, with China being by far the top destination. Soybean industry is representative of the logic of the contemporary international trade system with the annual (in 2023) imports of soybeans (434,000 t), soy-based meals (1.1 mt), and oil (223,000 t) completing this complex picture.

[12] Canola is a Canadian rapeseed largely produced for export markets. In 2023, out of a total domestic production of 2.95 mt (a relatively low yield year), 75 percent (2.43 mt) was exported. Imports were negligible at 16,810 t accounting for less than 1 percent of total domestic production.

[13] The conversion of crops that are suitable as human food into animal feed that is then converted by animals into meat edible by humans is, according to many, is "inefficient" (https://awellfedworld.org), and a diet based primarily on plant-forward foods can feed the world at much lower environmental and health costs (Willett et al., 2019).

therefore, are not only a source of income for farmers and processors, but also a significant source of embodied greenhouse gas emissions through animal production.

4 Farm incomes

While farm revenues, agricultural production and yields have, at least until recently, been increasing at robust rates, and while Canada remains a strong exporter of agricultural commodities, not only the number of farmers is decreasing, but farmers appear to be under constant financial stress. The root causes of farmers' financial woes are long standing and complex. Nevertheless, farm debt has been implicated:

> Canadian farm debt has nearly doubled since 2000 and now stands at a record $106 billion. Over the last three decades, the agribusiness corporations that supply fertilizers, chemicals, machinery, fuels, technologies, services, credit, and other materials and services have captured 95% of all farm revenues, leaving farmers just 5%. Qualman and the National Farmers Union (2019)

And that 5 percent is simply the average, because net farm revenues, measured by the difference between operating revenues and expenses, as a percentage of total revenues is unequally distributed across farm revenue classes. Here we report data on operating expenses and revenues from 2015 to 2022 across all farming operators, eight revenue classes, and across all provinces, as well as nationally (Figure 5A). Across all provinces and over the seven years for which we have consistent data, an average farm within the lower revenue classes (less than $100,000) often faces operating expenses exceeding their revenues, and at times at a margin of 1.5 to 1. Such economic losses speak in part to the fact that a crop failure or a viral disease (such as the one implicated in the recent global African swine fever outbreak) can have a large and devastating impact on the financial viability of many farm operators, especially of those that carry significant debt.[14] These margins are not necessarily driven by differences in small versus large farms as measured by area or the number of livestock. A large hog farm, in a catastrophic African swine fever outbreak, can have substantial operating expenses and yet little to no revenues.[15] At the same time, the expenses-to-revenues are considerably lower for larger revenue classes suggesting that an average farm in those classes is also operating at a more favorable financial margin.[16]

[14] In fact, the number quoted by Qualman and the National Farmers Union (2019) for 2018 has since grown to $139 billion in 2022, the latest year for which we have data (Statistics Canada. Table 32-10-0051-01). This puts the farm debt-to-revenues ratio at 128 percent, and the debt-to-revenues net of expenses ratio at 686 percent. It is notable that, in Canada, the federal government offers a mediation service between creditors and borrowers specifically targeting farm debt in stress, called Farm Debt Mediation Service.

[15] Farmers, unlike factory operators, cannot turn production on and off—their production has significant upfront investment expenditures in their crops or livestock, none of which are recoverable in the event of a crop failure or animal disease outbreak. Textbook economic models have considerable difficulty dealing with issues such as debt, bankruptcy, and insolvency, and those models that incorporate such notions remain highly stylized and abstract.

[16] Unfortunately, these data are only available in current prices. Due to a general increase in the prices of all commodities and services, we would expect the number of farms in each of these revenue classes to decline over time—an instance of "bracket creep". Declining farm operator numbers in each revenue class would thus tend to reduce the share of expenses and revenues accounted by farms in lower revenue classes.

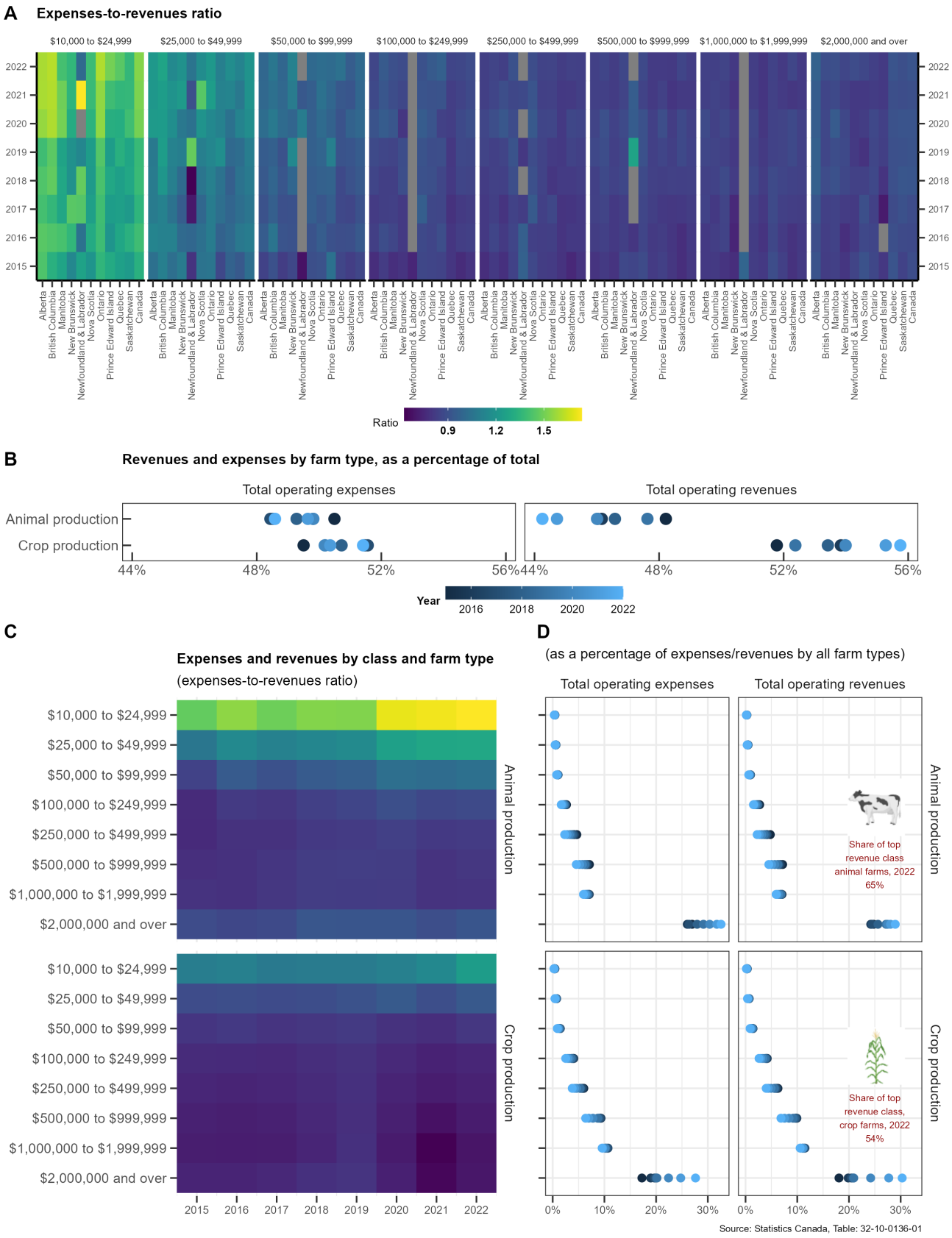

Figure 5: Farm expenses and revenues by farm type and revenue class

Animal and crop production tend to have different expenses-to-revenues ratios. While animal production accounts for less than half of all farm revenues, it also accounts for about half of all farm expenses—indicating that on average crop farming tends to be more economically profitable (Figure 5B). Within animal and crop farming, farm operators in higher revenue classes also have lower expenses-to-revenue ratios (Figure 5C). However, this is not uniform within animal farming, with the highest revenue-class operators (the largest farms) exhibiting relatively high expenses-to-revenues ratios. Between the farm operators specializing in animal and crop production, crop producers tend to have lower expenses-to-revenues ratios across all revenue classes. Nevertheless, with the concentration seen in the industry, both revenues and expenses are increasingly concentrated in the largest revenue classes ($ 2,000,000 and over) (Figure 5D), with crop farming leading the way in medium and large revenue classes. Among the farms engaged in animal production, in 2022, those with operating revenues $ 2,000,000 or over accounted for about 65 percent of all revenues in animal production. In crop production, the corresponding share was 54 percent, and has increased significantly over time. While farms with revenues $ 2,000,000 account for less than 3 percent of all farms (Figure **??**A), in 2022 they accounted for about 60 percent of all farm revenues (Figure 5D).

It is difficult, with the available data, to extend this analysis to differences across farm types within crop and animal production. Here we present data for 2021 based on six types of animal farming (beef cattle, dairy cattle, hog and pig, poultry and egg, sheep and goat, and other animals), and five types of crop farming (fruit and tree nut, greenhouse, oilseed and grain, vegetable and melon, and other crops). For each type we have six income classes (Figure 6A). Within animal farming, in 2021, poultry and egg production had the highest share of farms within the top two income classes ($100,000 or more). Crop farming, on average, commands a relatively higher income per farm. There are major differences in terms of shares of crop farms classified by operator income class, in 2021, a larger fraction of fruit and tree nut and greenhouse farm operators had revenues $ 250,000 and over. Nevertheless, not only crop farming has on average relatively higher share of farms within the medium and top operator income classes, the differences within crop farming across different farm types does not appear to be significant. In other words, crop farms, regardless of whether they specialize in greenhouse, vegetable, grain or oilseed farming, seem to have similar financial income profiles and distributions.

Within animal farming, beef cattle and dairy cattle remain the farm types with the largest number of farm operators (Figure 6B), and within non-animal farming, oilseed, grain and other field crops are the farm types with the largest number of operators. Overall, fruit, tree nut, greenhouse, vegetable, and melon operators also tend to be those with relatively high incomes, but their numbers are relatively small.

5 Production support programs

Against this backdrop—a declining number of farms and farmers, increasing concentration in farm production, a precarious financial outlook for Canadian farmers, despite decades long increases in production, input use, and yields, and given that about 75 percent of Canadians have diets that are

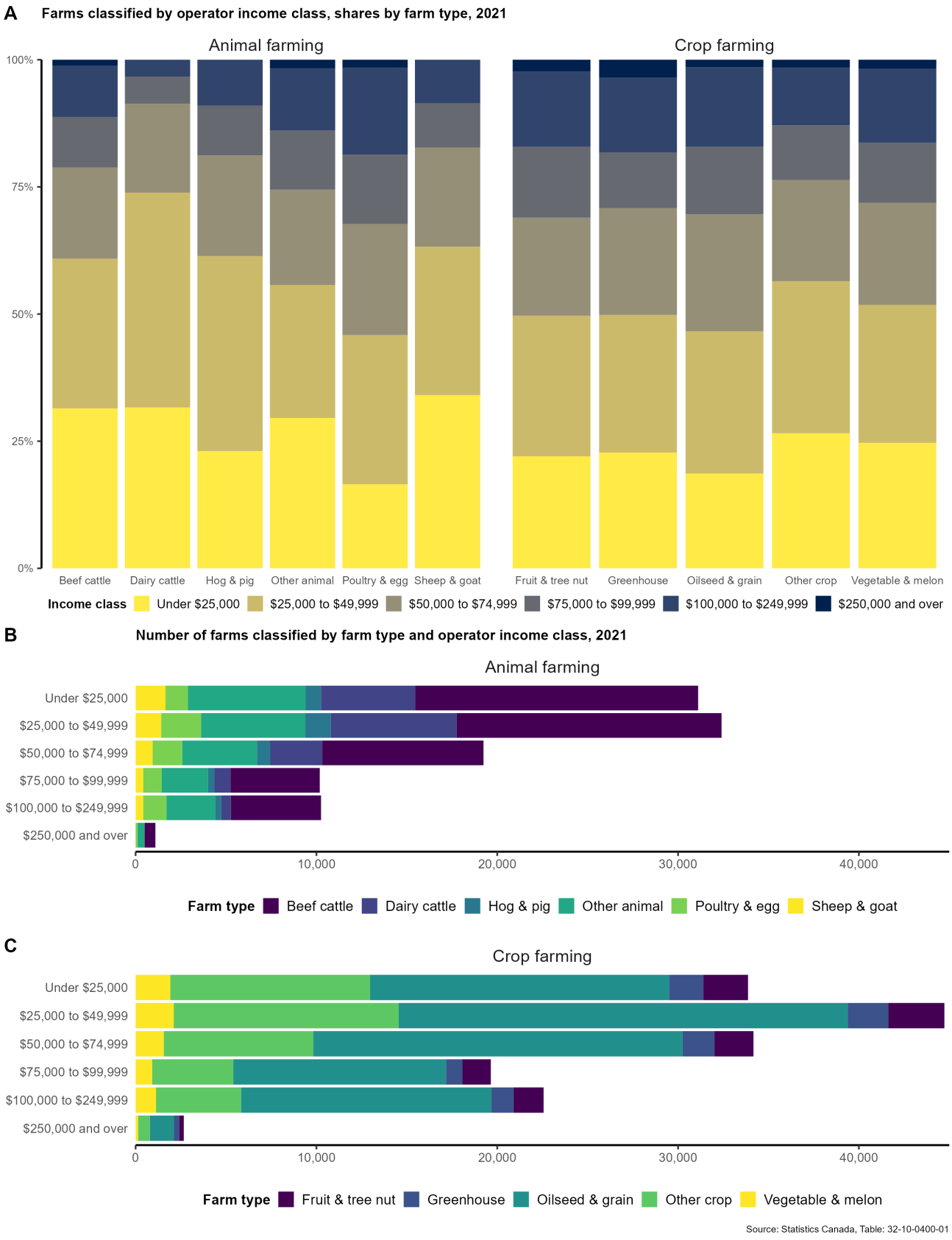

Figure 6: Number of farm operators by income class and farm type

not aligned with those recommended by Health Canada, we pose: what policies are in place to support farmers? Critical overviews of farm policies in Canada already exist (MacRae, 2011) and annual OECD publications within the Agricultural Policy Monitoring and Evaluation program summarize existing national policies and policy changes over time (OECD, 2023). Here we provide a brief background.

5.1 Policy framework

In Canada, agricultural producer support policies work differently across commodities. Supply-managed systems control domestic supply through a quota system. Supply-managed commodities consist of eggs, dairy (raw milk), and poultry (chickens and turkey). Their domestic market prices tend to be above the border market price. This translates into a positive market price support and amounts to a transfer from consumers to producers; there is no budgetary transfer from taxpayers and general revenues to producers. These transfers have two concrete implications: they stabilize the income received by farmers and suppress the volume of purchases of these products by consumers. If lower border prices were to prevail domestically, domestic producers that operate with narrow margins would exit the industry, incomes would be lower and more volatile, and Canadian consumers would likely consume more of the supply managed products provisioned by higher imports.

Transfers from taxpayers to producers, in contrast to market price support programs, tend to stimulate production. Canada eliminated its market support programs for grains in 1995 (OECD, 2023). Export subsidy programs for milk products were phased out by 2020 and import restrictions on milk producers in the United States and Mexico were eased due to Canada's international trade commitments. To mitigate the impact of enhanced market access by foreign milk producers on domestic dairy farmers, the federal government of Canada, through its Dairy Direct Payment Program has earmarked, starting from 2023–24, $ 2 billion over six years to cow's milk producers.[17]

More recent agricultural support programs have two major components: promoting "innovation; competitiveness and market development; and adaptability and industry capacity" and "risk management".[18] The risk management component is conceptualized as an "insurance" program against fluctuations in farmers' incomes, where private income insurance markets or their substitutes are missing.[19] Based on the research undertaken and to the best of our knowledge, these programs are not explicitly designed to promote public health, to address the environmental impact of agricultural production, or with distribution of resources across different farm types in mind, although they are framed as Sustainable Canadian Agricultural Partnership (Sustainable CAP).[20]

[17] Schmitz (1983), summarizing the earlier body of work on the detrimental welfare consequences of the systems of supply management in Canada, concluded that "one could easily reverse these conclusions by changing the assumptions upon which past research has rested." Looking at the differentials between the border and domestic prices, Cardwell et al. (2015) find the systems regressive with a financial burden equivalent to 2.3 percent of the annual income of the poorest households in Canada. Canada's supply management systems receive support from farmers in Canada (National Farmers Union, 2024).

[18] The quotes are from a concise submission (G/AG/N/CAN/121) to the World Trade Organization by the Canadian delegation dated 29 May 2018.

[19] National Farmers Union (2024) argues that supply management functions as an income insurance mechanism.

[20] Europe's CAP (Common Agricultural Policy) has been under considerable pressure to become more sustainable (IPES Food, 2019). There are many lessons that can be learned from the intended but resisted, compromised, and

5.2 Agricultural producer support: total estimates

Here we focus on financial support and transfers to farmers from taxpayers (from all levels of government) or from consumers, through supply management, tariffs, and quotas. OECD (2023) data on agricultural production support policies start in 1986 (Figure 7A) and reported, for the purposes of international comparability) using several core measures all reported relative to a broad metric (Box 2).[21] We reproduce these estimates and confirm the overall decline over time in the agricultural producer support as a percentage of gross farm receipts (GFR), total budgetary support as a percentage of gross domestic product (GDP), and total agricultural producer support estimates as a percentage of GDP. There has, however, been an increase over time in general services support (GSS) as a percentage of total support estimate (TSE). GSS is a broad category (Box 2) and is not informative about farm types targeted by these programs.

While many general services support programs benefit all farm types, there are also services that target producers of specific commodities. OECD thus reports producer single commodity transfers (PSCT). These PSCT estimates are around 80 percent of total budgetary support, financed by taxpayers (Figure 7C), and this share has increased since the early 2000s. Total support estimate, which includes transfers from taxpayers and consumers, as a percentage of total budgetary support has fluctuated over time, but have recently declined to historically low levels. So, the financial "burden" of the agricultural sector on fiscal budgets and consumers has been declining over time.

An alternative way to appreciate the significance of these support programs is by evaluating them relative to net operating income of farmers. Statistics Canada has been publishing net operating income data on an annual basis since 2015 based on administrative tax records. The OECD agricultural support estimates when measured against farm operating income provide information regarding the importance of these support estimates for farmers. The longitudinal data we have is short and includes restrictions and programs related to COVID-19 and as well as the supply-chain issues in its aftermath. Despite these considerations, the significance of the existing support programs for the agricultural sector is immediate (Figure 7B). Total budgetary support for agriculture is about 35 percent of net operating income of farmers. Total support is about 50 percent. Thus, while the ramifications of agricultural programs for fiscal budgets and consumers have been diminishing over time, net operating incomes of farmers continue to remain low relative to the support they receive.[22]

An alternative source of agricultural producer support is the data published by Statistics Canada on net programs payments to farm operators (Box 3). In 2015 these payments were about a third of what OECD calls producer single commodity transfers and one sixth of OECD's total support esti-

ultimately failed European CAP reforms.

[21] These are: consumer support estimate as a percentage of value of production; general services support estimate (GSSE) as a percentage of total support estimate (TSE); producer support estimate (PSE) as percentage of gross farm receipts (GFR); total budgetary support estimate (TBSE) as a percentage of gross domestic product (GDP); total support estimate as a percentage of GDP. Below, we also report all the estimates in the numerators as a percentage of farm net operating income (NOI).

[22] In terms of prices of agricultural commodities globally, there are cyclical variations and across commodities. However, since the second decade of the 2000s commodity prices in general, and agricultural commodity prices in particular have been relatively high, boosting the revenues of farmers.

Box 2 OECD's main agricultural support indicators: definitions and examples**.**

OECD (2023) uses a number of indicators that track agricultural support programs in a way that is comparable over time and across countries.

The **producer support estimate** (PSE) is the monetary value of transfers from consumers and taxpayers to agricultural producers due to policies that provide support to agriculture. In Canada, these transfers are arise from supply managed production systems, import restrictions, or direct income transfers to farmers.

The **consumer support estimate** (CSE) is the monetary value of transfers to consumers of agricultural commodities. Food subsidies that reduce the cost of agricultural commodity purchases by consumers are included here.

The **general services support estimate** (GSSE) is the monetary value of transfers through privately or publicly-provided services and institutions that primarily support the agricultural sector and that do not involve any direct payments to individual producers or consumers. In Canada, General Services Support is a collection of several programs available to producers and agri-businesses. At the time of the writing, there were a number of Agricultural Programs and Services (accessed 13 March 2024). For example, two programs listed therein relate to industry "promotion":

- AgriCommunication Program (federal): non-payable contributions up to $8 million must support "activities which increase appreciation and pride in the contributions of farmers and the food industry and enhance public trust. The activities will help strengthen public trust about the origin of the food Canadians eat and how it is produced."
- Agri-Food Trade Services (federal): support the "Canadian food industry and businesses reach international markets."

Producer, consumer and general services support estimates are annual, gross measures (reverse transfers are not netted out), calculated at the farm gate level (except for GSSE), and can be wide-ranging in terms of their impacts on farm production or income. Whereas producer and consumer support transfers directly affect producer receipts or costs to producers and consumers, general services support transfers do not. OECD (2016) provides a detailed discussion of each of these concepts.

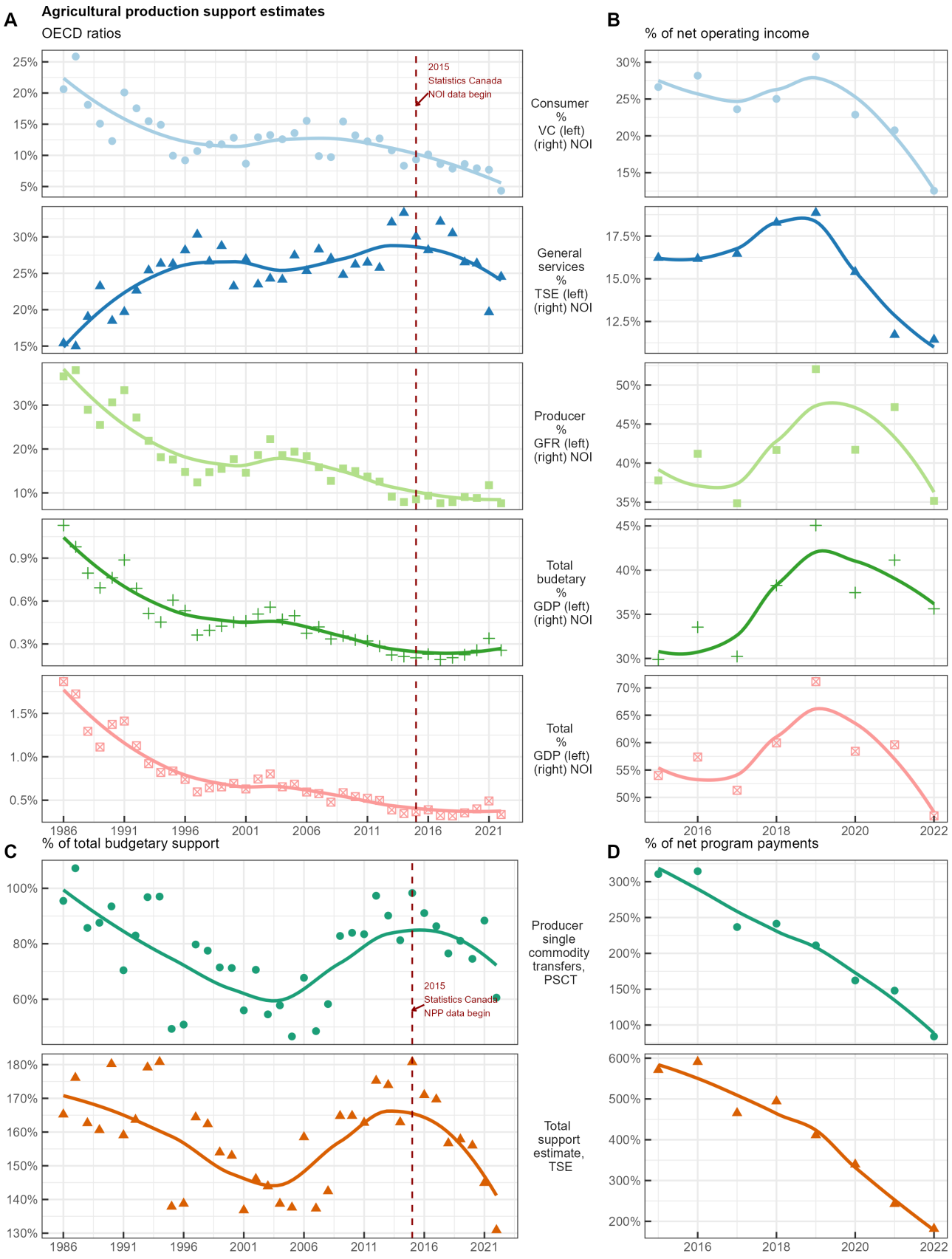

Figure 7: OECD agricultural production support indicators

Box 3 Statistics Canada's Net Program Payments: examples**.**

We use net program payments reported by Statistics Canada to complement the OECD data and to evaluate the distribution of agricultural support programs across farm types. According to Statistics Canada (personal correspondence, email dated 8 March 2024) the "Revenue - Program payments and insurance proceeds" variable is the sum of the following components:

- Program payments revenues
- Crop insurance
- NISA payments
- Disaster Assistance Program payments
- AgriStability and AgriInvest benefit
- Production insurance premium benefit
- Stabilization payments
- Rebates
- Insurance proceeds

AgriStability is within the suite of programs that are intended as an income insurance against substantial declines in farming income margins as a result of crop failure, increased costs and changes in market prices. Program payments are linked to a producer-specific historically calculated reference revenues-to-expenses margin and are triggered when the current year's margin drops below 30 percent of the reference margin. The federally funded Advance Payments Program pays, for loans up to $1,000,000 for eligible products, the interest on the first $100,000 ($250,000 for 2024) of the loan with a repayment period of up to 18 months for most commodities and up to 24 months for cattle and bison. Dairy Direct Payment Program, intended to support dairy producers who will be affected by the Canada-United States-Mexico Agreement that gave market access to dairy imports earmarked $1.2 billion over 6 years with $300 million in 2023-2024, so that "an eligible producer with 80 cows could receive around $26,500 in 2023-24" (accessed 13 March 2024).

mates (Figure 7D). However, within seven years there has been a dramatic change in the composition of Canadian agricultural support system so that by 2022 net program payments were higher in monetary value than producer single commodity transfers, and slightly less than half of the total support estimate. Thus, net program payments are becoming the most significant agricultural support policy instrument in Canada.

5.3 Agricultural producer support by commodity

OECD's agricultural producer support estimates broken down by commodity and distinguished as transfers from consumers and transfers from taxpayers illustrate the changes in the composition of

support programs (Figure 8A).[23] Since the termination of grain market price support programs in 1995 these estimates have uniformly pointed to animal agriculture as the main recipient of transfers both from consumers and taxpayers. This is in part the result of supply management in eggs, milk, and poultry. However, beef and veal have also received non-negligible support. In fact, as recently as in 2020, animal agriculture received more than 80 percent of total producer single commodity transfers (Figure 8A). From 2020 to 2022, eggs, milk, and poultry meat were the only commodities that received transfers to producers from consumers through supply management systems. In the cases of poultry meat and milk, these transfers exceeded half a billion dollars on average. Transfers to producers from taxpayers were also concentrated among those three commodities. Producer single commodity transfers also demonstrate considerable concentration of Canada's agricultural producer support directed to animal agriculture with support exceeding on average half a billion dollars a year in each case (Figure 8C–E).

Net program payments are a narrower concept than OECD's agricultural producer support estimates because they do not incorporate estimates of transfers from consumers to producers. Some of these payments also have "insurance" component where farmers are required to pay a premium. Yet they provide insights to shifts in agricultural support programs in Canada amounting to on average $3.73 billion per year over the 2019-2002 period (Figure 9A). Alberta, Saskatchewan, Quebec and Ontario are by far the largest recipients of these program payments. Over the period from 2019 to 2002, crop producers were the main recipient of these payments with on average $2.52 billion per year as opposed to $1.21 billion per year by animal producers, with the share of program payments received by crop production increasing steadily over time (Figure 9B).[24] The difference between the shares of support received by animal and crop production is due to the omission of OECD estimates of transfers from consumers to producers, driven by supply management.

The distribution of net program payments across revenue classes and farm types illustrates that farms within higher revenue classes also receive a larger share of these payments (Figure 9B). Farms with annual operating revenues $2,000,000 and over receive about 45 percent of all the payments, with 15 percent received by animal producers and 30 percent by crop producers. Farms in the lowest three revenue categories receive a negligible share of the payments.

We can assess the significance of net program payments for animal and crop production by comparing these payments to total operating revenues (Figure 9D). Net program payments as a percentage of total operating revenues is not only non-negligible for all revenue classes and in all provinces, but their financial importance has also increased over time, especially for animal production. Several components of net program payments function as a social safety net for farmers. However, it is important to assess whether the safety net is appropriate for the broader societal goals.[25]

[23] The heatmap scales the value of transfers as percentage of value of production to better visualize the changes over time.

[24] Total NPP for 2022 was $5.2 billion, split between $1.6 billion for animal production and $3.6 billion for crop production.

[25] We do not claim that all the transfers and program payments we document here turn into net income for farmers. We are aware of many economic and financial mechanisms that divert these funds away from farmers, who thus are not the sole beneficiary of these supports. An OECD report "Transfer Efficiency of Agricultural Price Support" (OECD,

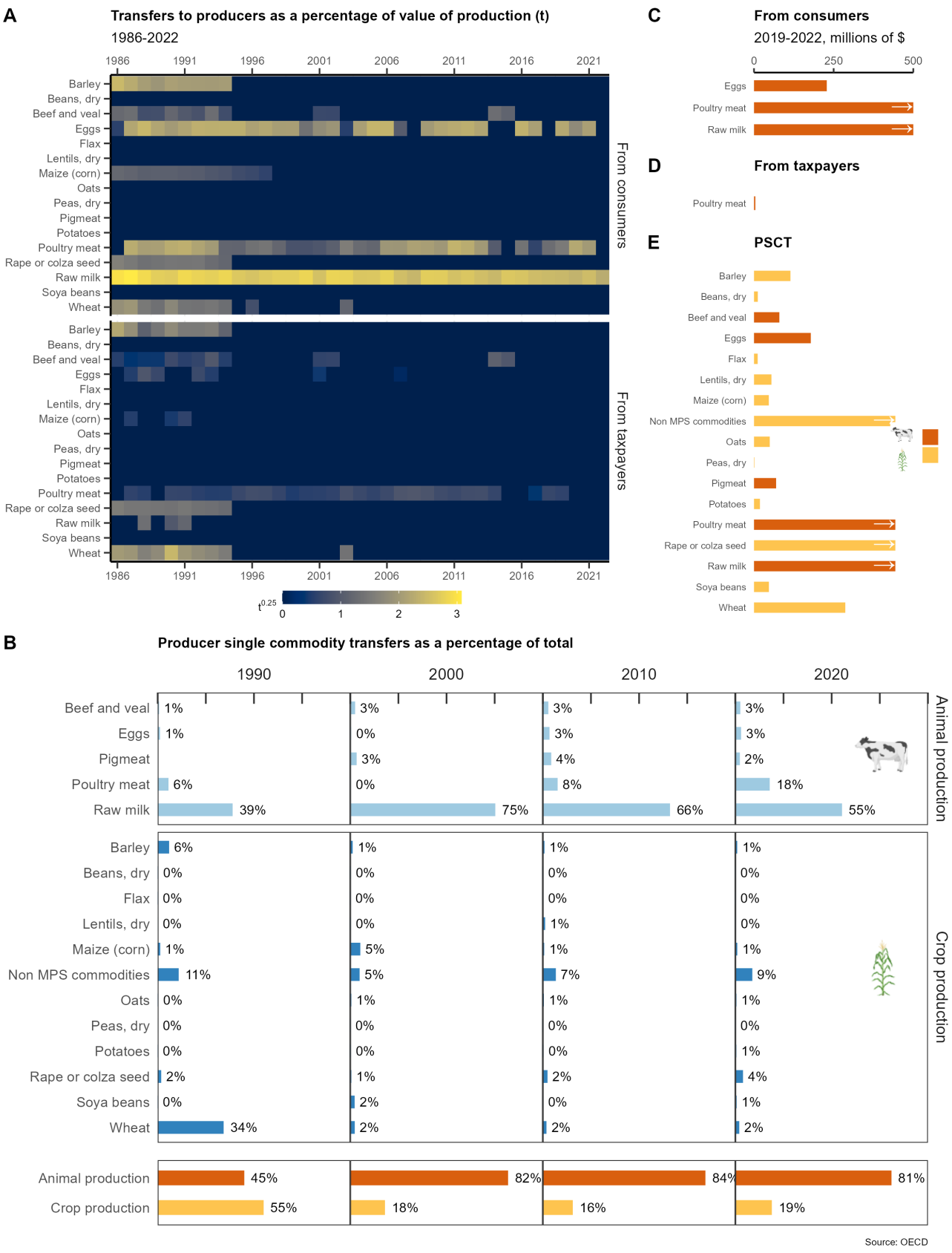

Figure 8: OECD agricultural producer support estimates by commodity

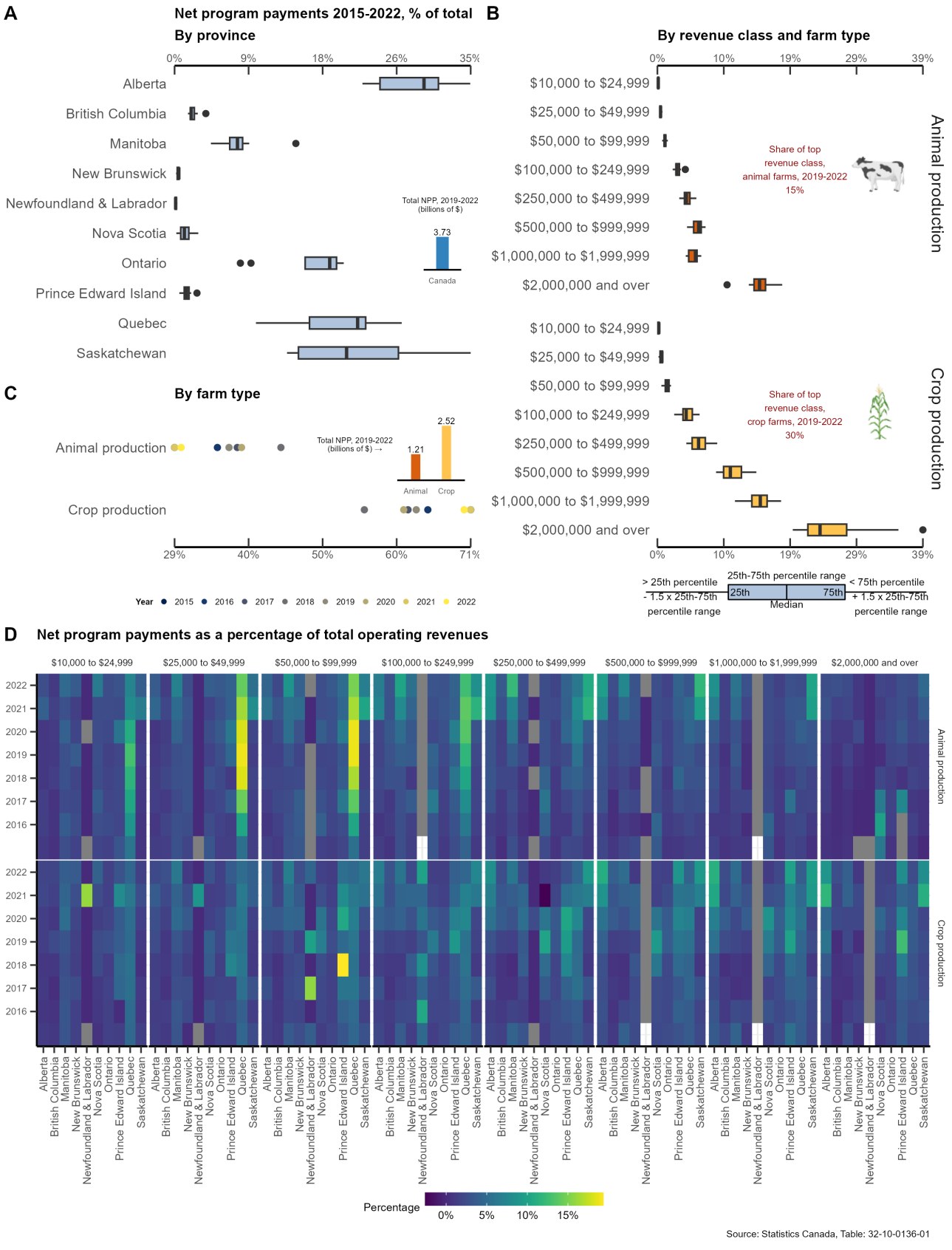

Figure 9: Net program payments

5.4 Distributional impact of support policies

OECD data lacks a window on the distributional consequences of these support programs. Services are not explicitly designed to stimulate production. At the same time, their structure and payments result in larger payments to larger producers. One early study (OECD, 1999) on the distribution of support received by farmers found that agricultural support received by farms was more concentrated than gross farm output, with a disproportionate amount of support going to larger producers. This concentration of support ended up increasing the concentration of farm receipts, tilting the distribution of income within the agricultural sector even more towards larger farms. As a result, agricultural support programs made the distribution of farm income less equal.[26]

The implications of agricultural support programs for the distribution of income across farm operators in Canada has not been addressed since the OECD study. Unfortunately, without access to confidential micro files it is not possible to replicate the results in this study. However, we can shed light on this topic by combining several data sources published by Statistics Canada on net program payments. In 2016, the share of the top revenue class ($2,000,000 and over) were only 3 percent of all farms (in 2015 constant dollars). We do not, unfortunately, have information on this share in 2022 and in current prices. While the share of the top revenue class has almost certainly grown from 2016 to 2022, it most likely remained in single digits. Yet, in 2022 alone, farms within this top revenue class in Canada received about 50 percent of all net program payments, with animal farm operators in the top revenue class receiving slightly under 15 percent of the total and crop farm operators in the top revenue class receiving 35 percent. Moreover, given that many crops are primarily turned into animal feed (Figure 4), these distributional considerations can be particularly problematic from an efficiency perspective.

6 Concluding remarks

We presented a brief overview of Canadian agriculture's evolving structure and the best scientific evidence regarding the destination of agricultural support. Informed by these observations, we would like to consider what rational policy choices might guide Canadian agricultural support policies; how might supports be repurposed to achieve broader economic, health, environmental and equity ambitions of Canadians? We don't claim that we have the answer. But we think that an informed and open-minded debate is needed and timely.

The Ontario-based campaign statement that "farmers feed cities" is a reality: in fact, a *shrinking* number of farmers are feeding our cities. And agriculture's direct and indirect economic impacts including on GDP, jobs, and budgetary revenues for all layers of government remains strong. Even

1995, cited in OECD, 1999) concludes that out of an additional dollar of transfers from consumers and taxpayers to producers less than 65 cents, perhaps as little as 25 cents translates into additional net farm income. The rest is captured by the processors, wholesalers, and retailers in the entire value chain. The capture is higher the higher the pricing power of upstream companies that supply farm inputs and downstream companies that purchase the farm output. OECD has not updated its estimates of such "leakages".

[26] As one recent editorial noted "In France, the farming profession displays high inequality with a minority of wealthy industrial farmers reaping most of the public subsidies" (Chapron, 2024).

high emission intensive commodities such as beef are contributors to the national economy (Windfeld and Lhermie, 2022). But such economic considerations alone, based on distorted prices influenced by varied support systems, and without explicitly accounting for their external costs, form only part of a broader economic, social, and environmental calculus. It is essential to approach the topic from a systems perspective, and by acknowledging all the economic, environmental, health and dietary ramifications of agricultural producer subsidies (FAO, UNDP and UNEP, 2021). Given the near complete lack of health policy considerations beyond food safety in the formulation of agricultural policies and subsidies, the net effect of these policies on public health in Canada cannot be accepted as being positive, as more comprehensive accounting frameworks have recognized and recorded not only increasing food production but also increasing harm arising from Canada's largely industrialized, animal-centric food systems.[27]

[27] Cash et al. (2006) estimate, using dietary data from 1993, the health costs of four diet-related diseases (heart disease, cancer, stroke, and diabetes) at about 19% of all health care costs in Canada. Using dietary data from 2004, Lieffers et al. (2018) who attribute chronic diseases to diets that do not meet recommended food intakes (primarily fruits, vegetables, nuts, seeds and whole grains) find that annual direct costs amount to 2 percent of total health expenditures.

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Supplementary Material

for

Reorienting our food systems for greater sustainability: potential policies and strategies [*]

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S.1 Supporting evidence

(Footnote 1) Planetary boundaries for Canada. Fanning et al. (2022) used the following indicators: CO_2 emissions, biogeochemical (phosphorus and nitrogen) flows, land-system change, and ecological and material footprint. More comprehensive indicators of planetary boundaries include freshwater use, biosphere integrity, stratospheric ozone depletion, atmospheric aerosol loading, and ocean acidification (Steffen et al., 2015). Agriculture is implicated in the transgression of nitrogen and phosphorus flows and land-system change, as well as in greenhouse gas emissions (methane and nitrous oxide) implicated in climate change.

(Footnote 2) How healthy is Canadian diet? In 2004, only 26% of the non-infant population consumed the minimum number of daily servings of fruits and vegetables recommended by Health Canada, with average dietary intake of fruits and vegetables not exceeding the 40% of daily recommended values (Black and Billette, 2013). About a quarter of all adults, 19 years and older, had dietary fat in excess of the Accessible Macronutrient Distribution Range (Health Canada, 2012). On any given day in 2015, about 94% of Canadians consumed dairy products, and 63% consumed meat, and yet only 14% consumed legumes (Statistics Canada, 2018).

This diet is shaped by multiple factors. Canadians prepare and eat food at home, and eat out prepared food. In 2021, an average Canadian household spent CAD$ 10,305 on food (15 percent of their total consumption) with 21 percent of the food purchased from restaurants, though this share was negatively affected by COVID 19 restrictions (Statistics Canada, Table 11-10-0222-01, and Table 11-10-0125-01). Monthly restaurant sales in April 2023 were about CAD$ 7 billion, almost equally split between full-service and limited service ("fast food ") restaurants (Statistics Canada, 2023). In 2015, about 22 percent all Canadians reported consuming food away from home on the previous day and on average the restaurant food they consumed is less healthy, consisting of less vegetables (not including potatoes), whole grains and fibre, and more total fat (Polsky and Garriguet, 2021).

(Footnote 3) Lawyers about to outnumber farmers in Canada. In Canada, by law, every lawyer, and in the case of Quebec, every notary, is required to be a member of a law society. So "counting" the number of the legal professionals is relatively straightforward. According to the Federation of Law Societies of Canada "Canada's 14 provincial and territorial law societies govern over 136,000 lawyers, Quebec's 4200 notaries and Ontario's 10,600 independent paralegals in the public interest." (Retrieved 6 March 2024). That is about 151,000 lawyers, notaries, and independent paralegals, as of 2024. According to the 2021 Agricultural Census, there were about 190,000 farms in Canada, down from 205,700 in 2011 and 193,500 in 2016. While a lawyer registered with a law society is most likely actively practicing law, not all farms are operational and many farmers are actually employed (many full time) off the farm. If we think of farm receipts as an indicator of an operational farm, about 44,000 of the 205,700 farms in 2011 and 34,000 of the 193,000 farms in 2016 reported under $ 10,000 total gross receipts, excluding sales of forest products (Statistics Canada Table: 32-10-0436-01). So, it is quite conceivable that in Canada by 2024, the number of lawyers was roughly equal to the number

of farmers operating economically viable farms.

(Footnote 27) Direct health care costs of unhealthy eating. Lieffers et al. (2018) use food intakes from the 2004 Canadian Community Health Survey 24-hour dietary recalls, and find diets that do not meet the recommended food intakes lead to direct health care costs of CAD$ 5 billion per year in 2014 prices. According to the National Health Expenditure Database, 2023 by the Canadian Institute for Health Information (accessed 12 June 2024), in 2014, total health expenditure in Canada was CAD$ 219,260 million.

S.2 Units of measurement

Table S.1: Conversion rates

Unit 1	=	Unit 2	×	Conversion	Source
Metric tonne / Tonne (t)		Kilograms		1000	SI unit convention
Million tonnes (mt)		Metric tonnes (t)		10^6	SI unit convention
Megatonnes (Mt)		Million tonnes (t)		100	SI unit conversion
Gigatonnes (Gt)		Megatonnes (Mt)		1000	SI unit convention
Metric tonnes (t)		Pounds (U.S.)		2205	U.S. customary unit
100y GWP CO_2 eq		CH_4		34	IPCC (2019)
Nitrogen, N		Crude protein		0.16	Poore and Nemecek (2018)
Canola oil		Canola		0.43	Canadian Grain Commission*
Soybean oil		Soybean		0.19	Canadian Grain Commission†
Beef cattle					
Dressed carcass‡		Live weight (LW)		0.63	UNL Beef
Nutrient composition, g N		Live weight, 1 kg		26.5	Poore and Nemecek (2018)

* Quality of Canadian canola 2023. Harvest samples of Canadian canola graded No. 1 at 8.5% moisture, 2018 to 2022 mean (accessed 21 May 2024).
† Quality of Canadian oilseed-type soybeans 2023. Composite samples of Canadian soybeans graded No. 1 and No. 2 at 13% moisture, 2018 to 2022 mean (accessed 21 May 2024).
‡ Relative dressing weight is based on hot carcass weight for a traditional feedlot beef type and includes bones, excess fat and moisture removed during processing.

S.3 Data sources

We use agricultural producer support estimates from two sources, OECD, and Statistics Canada. These two sources have their relative strengths and weaknesses. OECD's Producer and Consumer Support Estimates linked to an annual publication titled "Agricultural Policy Monitoring and Evaluation" (OECD, 2023) with annual themes. This database originates from an OECD project called "Agricultural Policies in OECD Countries: Monitoring and Evaluation" and contains, for the European Union and for every other OECD Member country, estimates of market price support (MPS) for a common list of commodities: wheat, maize, barley, sorghum, rice, oilseed rape (canola), soybean, sunflower, sugar, milk, beef, pigmeat, poultry, eggs, sheep meat, and wool. The objective of comparability across countries has dictated this common list that has been tracked. Over time, this list has expanded and now includes commodities like pulses, and cotton. OECD supplements its in-house modelling of MPS by data on other consumer and producer support data, like General Services Support Estimate (GSSE), which are not at the commodity level. OECD obtains these consumer and producer support data from the appropriate agencies of the reporting countries. OECD data are available annually since 1986. The OECD producer support estimates are not disaggregated by farm size in acres or farm size in revenue classes.

Statistics Canada publishes data on the agricultural sector, including farm revenues and expenses. Part of the farm revenues reported by Statistics Canada consists of "Program Payments and Insurance Receipts" and "Net Program Payments". These estimates cover all agricultural commodities and farm types, although the publicly available data are only disaggregated by crop and animal production. Statistics Canada data are available annually since 2015. There is one shortcoming of these data for longitudinal analysis: the revenue classes are not in quantiles or deciles but classified within revenue classes in current prices. As the general price level increases, these classifications are subjected to "bracket creep".

Aggregation of data at the farm type and commodity level can be problematic. Farm type classified by production has challenges outside monoculture operations. Different data sources track different commodity groups at different levels of aggregation. Whenever possible we report data that we judge to be comparable at the most disaggregated level. Table S.3 lists the commodity groups and farm types reported by our data sources.

S.4 GHG emissions

We rely on Canadian studies in Poore and Nemecek (2018). For barley, canola, corn, lentils, soybean, and wheat we use gross energy per kg of marketable dry matter (DM), and include emissions from drying, with the exception of soybean, reported in kg CO_2eq per 1000 kcal:

$$(\text{Emissions per hectare} * \text{year})(\text{Yield per hectare} * \text{year})^{-1}(\text{Gross energy per marketable DM})^{-1}$$
$$1000(\text{kg } CO_2\text{eq})(\text{kg})^{-1}(\text{kcal per kg DM})^{-1}.$$

For beef, emissions in kg CO_2 eq per 100g protein are calculated by (Table S.1):

$$(\text{Emissions per 1 kg LW})$$
$$((\text{N composition of cattle})(\text{Relative dressing percentage, RD})(\text{N to crude protein conversion}))^{-1}$$
$$100\,(\text{kg } CO_2\text{eq (1 kg LW)})\left((\text{g N (1 kg LW)})(\text{RD})(0.16)^{-1}\right)^{-1}.$$

Low GHG emissions per unit of output are desirable. Contrasting these with transfers to producers, one preferred outcome might be to see lower transfers to commodities that are primarily used as feed or exported (Table S.2). Transfers to commodities that are primarily used as feed are essentially indirect subsidies that often lack transparency. Transfers to commodities that are exported serve as export promoting subsidies, distort international trade, and channel domestic resources to international consumers.

Food balances accounting is consistent with production of calories differing from the sum allocated to food, feed and net exports. The differences are due to changes in stocks and estimation errors recorded as "residual" (Box 1). To illustrate our data, consider the case of lentils. Lentils are a relatively low GHG emitting commodity per 1000 kcal. For each 1000 kcal, it received from 2019 to 2021 on average 14 cents of producer single commodity transfers (PSCT). Of this 14 cents, more than 13 cents were accounted by net exports and food and feed were each accounted for 1 cent each.

Table S.2: Agricultural product GHG emissions

		PSCT per nutritional unit accounted by		
Commodity	kg CO_2eq	Food	Feed	Net exports
100g protein				
Beef and veal	16.040	0.042	–	0.012
1000 kcal				
Barley	0.028	0.015	5.663	4.484
Canola and mustardseed	0.070	0.036	0.087	16.745
Corn	0.048	0.002	0.018	−0.003
Lentils	0.159	0.011	0.010	0.135
Soybean	0.022	0.002	0.018	0.266
Wheat	0.073	0.004	0.005	0.028

PSCT is "producer single commodity transfers" as defined by OECD (2016).

Table S.3: Farm type by data source and R dataframe

OECD	Statistics Canada		FAO*
`commodity_indicators`	`revenue_expense`	`farm_operators`	`food_balances`
A Animal production			
Beef and veal	Cattle	Beef cattle ranching and farming, including feedlots	Bovine Meat
Raw milk	Dairy products	Dairy cattle and milk production	Milk - Excluding Butter
Pigmeat	Swine	Hog and pig farming	Pigmeat
Poultry meat	Poultry and eggs	Poultry and egg production	Poultry Meat
Eggs	Sheep, lambs and goats	Sheep and goat farming	Eggs
	Other livestock and animal products	Other animal production	Mutton & Goat Meat
B Crops, fruits, vegetables			
Barley	Barley	Oilseed and grain farming	Barley and products
Oats	Oats	Vegetable and melon farming	Oats
Maize (corn)	Canola (rapeseed)	Fruit and tree nut farming	Maize and products
Wheat	Wheat	Greenhouse, nursery and floriculture production	Wheat and products
Peas, dry	Corn	Other crop farming	Peas
Beans, dry	Mixed grains		Beans
Lentils, dry	Other and non-specified grains and oilseeds		Pulses, Other and products
Soya beans	Soybeans		Soyabeans
Potatoes	Potatoes		Potatoes and products
Rape or colza seed	Fruits		Rape and Mustardseed
Flax	Vegetables (non-greenhouse)		Sunflower seed
Non-market price support commodities	Greenhouse, nursery and floriculture products		
	Forage crops (including seeds)		
	Other crops		
C R source for farm types			
`commodities`	`estimates`	`prep_farm_operators.R`	`food_balances`

* FAO Food Balances include "Oil" categories for all oilseed products, vegetables, fruits, fish and shellfish, spices, alcoholic and fermented beverages—altogether 56 different food items grown, produced, fished, and foraged.

Table S.4: Correspondence between raw data and R data frames

Source	R dataframe		Description
A OECD			
Data Explorer	`total_indicators`		Agricultural Policy Monitoring and Evaluation database, 1986–2022
	`commodity_indicators`		
B Statistics Canada			
Table numbers			
32-10-0157	`farm_receipts`		Farms classified by total gross farm receipts, 2015 constant dollars, 1981–2016
32-10-0156-01	`farm_area`		Farms classified by total farm area distribution, 1976–2021
32-10-0154-01	`crops`	`farm_size`	Average size by area of crop farms, 1921–2021
32-10-0155-01	`livestock`		Average livestock per farm, 1921–2021
32-10-0359-01	`production_field_crops`		Estimated areas, yield, production, average farm price and total farm value of principal field crops
32-10-0013-01	`disposition_grains`	`use_grains`	Supply and disposition of grains in Canada (x 1,000)
32-10-0014-01	`disposition_corn`		Supply and disposition of corn (x 1,000)
Food balances[⋆]	`food_balances`		Food balances for crops
32-10-0136-01	`revenue_expense` [†]		Farm operating revenues, expenses and net program payments, 2015–2022
32-10-0400-01	`farm_operators`		Farm operators classified by farm type and operator income class, 2021

[⋆] FAO Food Balances (2010-).
[†] Source for `commodity_revenue_expense`.

S.5 Data validation

Table S.5: Lentils, pulses, canola and mustard seed production data

				Percentage				
Year	Lentils	Chickpeas + Faba beans+ Lentils (CFL)	Pulses	CFL / Pulses	Lentils / CFL	Lentils / Pulses	Canola / Canola + Mustard seed	Canola + Mustard seed / Rape and Mustardseed
2019	2382	2741	2798	97.97	86.89	85.13	99.33	100.00
2020	2868	3207	3312	96.82	89.43	86.59	99.49	100.00
2021	1594	1753	1783	98.34	90.89	89.38	99.58	103.55

Production are in 1000 Metric tonnes. Production data on chickpeas, faba beans, lentils, canola and mustard seed are from Statistics Canada, Table 32-10-0359-01. Data on "Rape and Mustardseed" are from FAO (2024).

S.6 Data gaps

Data released by Statistics Canada is highly aggregate, and does not provide detailed insights about the recipients of net program payments and by payment category. We are considering requesting more granular net program payments data by product (as in Figure 6, based on Table 32-10-0400-01, plus primary crops and animals) and by revenue class (as in Figure 9, Table 32-10-0136-01), either for the most recent year or for the last decade and in constant 2015 dollars (as in Figure 1, Table 32-10-0157).