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Odessa Sub-area Potato Production & Processing Impacts Under an Irrigation-Water Shortage

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Abstract

The Odessa Sub-area lies in the second, and uncompleted, region of Washington's Columbia Basin Water Project. Water used for irrigation in the region is currently pumped from as deep as 700 feet, and water access is steadily declining. We measure the economic losses to the potato producing region that would result from further reducing access to water for crop irrigation in the Columbia Basin. Estimated costs are adjusted for the gains in wheat production that would result as affected growers transition their land into the next best non-irrigated crop alternative in the region. Then, we move beyond the standard contribution analysis by looking not only at the net losses in production, but potential forward linked losses from potato processing plant closures.

Keywords: Alternative use, input-output, natural resources.

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Introduction & Background

In 1930, the Bureau of Reclamation began the Columbia Basin Project (CBP) for the purpose of irrigating the eastern portion of Washington State. This project was originally undertaken as part of the New Deal. Due to various economic and political issues, only the first half of the CBP was completed (670,000 acres). The Odessa Sub-area is one region of the CBP that never received irrigation water through the project, and as a result has relied on ground water pumping for irrigated crop production. Pumping rights for ground water were granted by the Bureau of Reclamation with the understanding that at the completion of the CBP, ground water pumping would cease.

Most groundwater wells were shallow in early years as there was little irrigation and shallow wells provided enough water for local demand. With the development of sprinkler technology, however, farmers began increasing irrigated acres and crop yields improved dramatically. Even though the CBP was never finished, improvements in irrigation efficiency enhanced crop profitability, driving acreage expansion.

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Small-diameter, shallow wells were soon replaced with 16” diameter wells extending as deep as 700 feet. Water quality at these depths is poor, and the mineral content can be detrimental to yields. Water from these depths is also warmer, which stresses plant health. Though there is some recharge to the aquifer, surface water canal seepage has caused the groundwater levels in the Odessa Sub-area to decline rapidly. In the absence of additional water supplies, potato production is at risk.

Since 2005, potato producing acres in the sub-area have declined from 35,600 to 26,519 acres (2015). However, the 25% acreage decline has been partially offset by increased yield per acre (from 595 cwt/acre in 2005 to roughly 635 cwt/acre in 2015). As a result, total production changed from 21.2 million cwt to 16.8 million cwt between 2005 and 2015, a decline of 20.5%.

Potential economic losses from reduced potato production in the Basin were initially estimated by Bhattacharjee and Holland (2005). The analysis here estimates the economic impacts associated with changes in water policies that would limit access to groundwater in the current economic environment. We then compare these losses to the costs of providing surface water to maintain irrigated potato acreage in the Sub-area area of the Basin currently relying on groundwater.

Odessa Sub-area Regional Description

Geography

The Odessa Groundwater Management Sub-area was designated by Chapter 173-128A of the Washington Administrative Code (WAC) for the roughly 1,800 sq. mile area under the Columbia Basin Project, commonly known as “Odessa Area” or “Odessa-Lind Area.” The area extends from Odessa on the north to Lind on the south, and from the East Low Canal on the west to Ritzville on the east (see Figure 1). This area is semi-arid with a higher precipitation on its eastern side than on its west. At the same time, the western border is adjacent to the fully completed portion of the CBP.

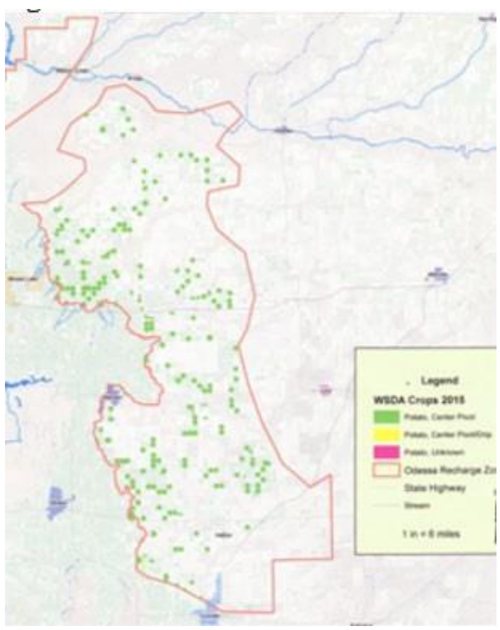

Figure 1. Odessa Sub-area and Potato Acres
(Source: WSDA 2015 Crop Data Reports and Harold Coase)

Agricultural economists focused on water allocation issues often specify regions using the hydrological rather than economic geography. However, where production occurs and contributions are felt are rarely the same. Imagine a contribution analysis on the commercial fishing industry. If the region of analysis were chosen based on the production site, the analyst would need to isolate some region of the ocean, but few market transactions actually occur where the fish are caught. Similarly, we cannot use the Odessa Sub-area alone as the geography for conducting an analysis associated with reduced potato production resulting from reduced access to irrigation water in the Odessa Sub-area. Because we are capturing the contributions of the potato growers, which are located in the Odessa Sub-area, we must include the Sub-area. However, we also need to capture the central economic region that benefits from other transactions that occur outside the area as a result of potato production within the sub-area (for example, processing of sub-area produced potatoes in a different location). As such, we use the four counties of Adams, Franklin, Grant, and Lincoln as our region of general impact (see Figure 2).

Figure 2. Four-County Economic Region (Source: Emsi 2017.1)

Why Potato Production in the Columbia Basin?

The distribution of agricultural production is often explained using the concept of Comparative Advantage. The Law of Comparative Advantage states that producers will specialize in producing commodities for which they have the greatest comparative advantage (or least comparative disadvantage) and then trade for commodities for which they have the least comparative advantage (Bessler and King, 1978). In this context, producers can refer to individuals, regions, or nations. Comparative advantage is not to be confused with absolute advantage. Producers in region A may have an absolute advantage in producing both potatoes and wheat compared to producers in region B (i.e., producers in region A face lower costs of production for both crops compared to producers in region B), but producers in region A focus on potato production because the net return to potatoes is greater than the return for producing wheat. Producers in region B will then have a comparative advantage in producing wheat if costs of production are lower than other potential wheat producing regions. Thus, under the Law of Comparative Advantage, producers in region A produce potatoes and producers in region B produce wheat even though producers in region A have an absolute advantage in producing both crops.

Gopinath and Roe (2000) note that comparative advantage can be influenced by public policy – policies that either influence crop prices or affect costs of production can influence comparative advantage across regions. As noted earlier, access to irrigation water in the Columbia Basin resulted in significantly increasing potato yields, and access to affordable irrigation water has helped establish a comparative advantage for potato producers in the Basin. Future policies which curtail affordable access to either surface (in the case of the CFB served areas of the Basin), or groundwater in the case of the Odessa Sub-basin could impact the comparative advantage of potato production in the Basin, and result in changes in the cropping strategies of agricultural producers. In turn, this impacts economic activity in the Basin if production shifts to lower valued crops.

Regional economists compare an industry in a region (a county) with the same industry in a larger geography (the nation) to assess whether the region has a comparative advantage in production. They do this by estimating a location quotient (LQ). A LQ of 1 simply says the industry is "average" or as concentrated regionally as it is nationally. A LQ greater than 1 says the industry is more concentrated regionally, and if it is less than 1 it is less concentrated. In general, if a region exhibits a LQ greater than 1 for a given industry then it assumed the region has a comparative advantage in that industry.

The LQ is calculated by taking an industry measure (output, employment, etc.) and dividing it by the associated total regional measure. The same calculation is then made for the industry at the national level. The ratio of the two then gives the industry's regional LQ, as shown in Figure 1.

$$\boldsymbol{LQ} = \left(\frac{\textit{Industry Regional Output}}{\textit{Total Regional Output}}\right) \Big/ \left(\frac{\textit{Industry National Output}}{\textit{Total National Output}}\right) \qquad (1)$$

Estimating a LQ, as defined by equation 1, we find that Washington State is roughly 8 times more concentrated than the nation as a whole in potato production, and that the four-county region in the Basin is approximately 132 times as concentrated as the nation in potato production (see Table 1).[3]

Table 1: Location Quotient for Potato Production ('000)

Region	Potato Production (Sales)	Total Regional Sales	Location Quotient
Four-County Region	$201,293	$6,023,766	132.4
Washington State	$771,210	$362,656,959	8.4
United States	$3,750,246	$14,863,510,830	1.0

Source: USDA NASS Quick Stats, Emsi, and author's calculations

[3] Location quotients were calculated based on production volume.

Thus, it is clear that the region currently enjoys a significant comparative advantage in irrigated potato production, and this is partly due to current water policy.

Current Proposals to Curtail Groundwater Irrigation in the Odessa Sub-Basin

As early as 2004, the Bureau of Reclamation, Washington Department of Ecology, and various irrigation districts within the Columbia Basin were seeking to find additional water resources for the region, including alternatives to ground water pumping in the Odesa Sub-area. In 2013, the Bureau of Reclamation selected the Odessa Ground Water Replacement Project as the preferred alternative to continued ground water pumping in the Sub-area. By 2016, the East Columbia Basin Irrigation District had authorized tax-exempt municipal bonds, totaling $16.8 million, to begin expansion of the East Low Canal as well as eight distribution systems. New contracts for ground water replacement were issued to landowners in 2016. In essence the program requires landowners who choose to use the newly available surface water to trade their current groundwater rights for surface water rights. Thus, once they participate, they lose the right to use groundwater for crop irrigation.

To date only one distribution system, EL47.5, has been funded and completed. Pump testing is currently underway and the first water from this system will be used in the 2021 growing season. The eight distribution systems range in infrastructure costs from $323/acre to $128/acre, averaging $247/acre for the entire project.[4] Under the current provisions, these costs will be borne by the irrigators themselves. However, there is a cost normalization provision that results in all farmers paying the same price per acre regardless of where they operate in the Sub-area. The normalization rate has been set at $190/acre. Most farms have opted to incur these costs, though a few have only transferred a portion of their groundwater rights to these new surface-water rights.[5]

Table 2 provides the most recent Russet Burbank potato enterprise budgets for Washington State (Galinato and Wohleb, 2019). Costs in the Odessa Sub-area will differ from these and are likely higher than average. Given the already negative estimated net returns, an additional $190/acre may result in financially unsustainable operations for many potato producers. Additional grant funding is being sought to reduce the burden on irrigators and maintain potato and agricultural production. In the absence of such funding, the threat of lost potato production remains even though a complete loss is unlikely given the increased water availability from the canal expansion.

[4] Payments from irrigators in EL47.5 will be $172.77 per acre, a portion of which is a result of the cost normalization provision.

[5] Most farmers are viewing their groundwater pumps as a sunk cost, not wanting to maintain them and pay for the additional electricity to use them.

Table 2: 2019 Costs and Returns per Acre of Producing Potatoes for Processing (Russet Burbank)

Total Returns:	**Unit**	**Price/unit**	**Quantity**	**Total**
Estimated Production (tons/acre)	tons	$175.00	31.5	$5,512.50
Variable Costs:	**Unit**	**Cost/unit**	**Quantity**	**Total**
Soil Preparation & Planting				
Tillage	acre	$100.00	1	$100.00
Planting	acre	$110.00	1	$110.00
Seed	cwt	$20.00	25	$500.00
Chemicals & Fertilizer				
Fertilizer	acre	$850.00	1	$850.00
Fumigation	acre	$380.00	1	$380.00
Fungicide & Insecticide	acre	$420.00	1	$420.00
Herbicide	acre	$77.00	1	$77.00
Irrigation				
Water and power	acre	$137.50	1	$137.50
Repairs - Center Pivot	acre	$25.00	1	$25.00
Labor	acre	$82.50	1	$82.50
Harvest				
Digging	tons	$8.25	33.0	$272.25
Hauling	tons	$8.00	33.0	$264.00
Cleaning and Piling	tons	$7.50	33.0	$247.50
Storage	tons	$24.00	32.0	$768.00
Other Variable Costs				
Monitoring	acre	$28.00	1	$28.00
Interest on operating capital (5% of VC)	acre			$213.09
Total Variable Costs	**acre**			**$4,474.84**
Fixed Costs:				
Management, Administration and Overhead	acre			$175.00
Regulatory Compliance	acre			$25.00
Land rent	acre			$850.00
Interest on fixed cost (5% of FC)	acre			$52.50
Total Fixed Costs	**acre**			**$1,102.50**
TOTAL COSTS	**acre**			**$5,577.34**
ESTIMATED NET RETURNS	**acre**			**-$64.84**

Source: Galinato and Wohleb (2019)

Measuring Impacts of Water Curtailment

The four counties considered in this analysis contribute about $6 billion to Gross State Product and employ roughly 16% of all agricultural employment in the state of Washington. Land devoted to agricultural production in the four counties is dominated by wheat (136,017 acres - 225,252 if fallow acres are included). The next largest crop is potatoes at 26,519 acres. Crops by acreage are outlined in Table 3. Crops with less than 2,000 total acres across all four counties were combined in the "All Other" category.

Table 3: Acreage by Crop Type, County, and Irrigation Rate

Crop Type	Total Acreage	Total Irrigated Acres	Percent Irrigated
Wheat	136,017	51,940	38%
CRP/Conservation	115,000	644*	1%*
Wheat Fallow**	89,235	9,382*	11%*
Potato	26,519	26,236	99%
Alfalfa Hay	9,867	9,702	98%
Pea, Green	9,251	9,228	100%
Corn, Field	5,916	5,916	100%
Bluegrass Seed	5,401	5,270	98%
Corn, Sweet	5,270	5,270	100%
Timothy	4,872	4,872	100%
Bean, Dry	4,141	4,049	98%
Onion	2,540	2,540	100%
Canola	2,024	1,874	93%
All Other	7,095	5,193	73%
Total	***423,148***	***142,116***	***34%***

* The data presented here reflects USDA survey data. The reader should not assume that CRP/Conservation or Wheat Fallow land is being irrigated. This land may have canals passing through it, but the land is not being actively irrigated.

**Because this data is based on surveys some land was not under production in a given year. This land is on two-year cycles.

Source: Washington State Department of Agriculture

Perhaps the most important information provided in table 3 is the percentage of acres irrigated by crop. It is clear that in the absence of water availability the only feasible agricultural land use is dryland wheat production. To account for this, we convert potato growing acres into wheat producing acres in our analysis and report the net changes to the economy one would expect if potato producers lose access to quality irrigation water.

While this research focuses on the loss of potato production and processing due to water curtailment, in reality if a water shortage were to occur all irrigated acres would likely move to dryland wheat production. As a result, our economic impact estimates represent a lower bound of expected outcomes if access to water is curtailed.

Net analyses associated with changes in an economic region are not uncommon, and in an ex ante case are preferred. Hamilton et al. (1991) argued factors of production have opportunity costs and those costs may be accounted for in both backward and forward linked effects. Accounting for such costs is key when using regional input-output models. Not accounting for them assumes factor idleness or a lack of resource mobility, i.e., there is slack in the economy. This is reinforced by Watson et al. (2007) who suggested impact analysis should be defined as “net changes” in economic activity, as opposed to the popular, but mislabeled, contribution analyses which are conducted on a gross change basis. In a later paper, Watson et al. (2015) stated that all *ex ante* economic impact analyses need to account for opportunity costs, in our case alternative land uses. They further cite Waters et al. (1998) in making the argument that contribution analyses should only be done on an *ex post* basis where all economic activity sums to gross regional product.

Similar to the research presented here, Koirala et al. (2020) conducted a net impact analysis of the presence of pale cyst nematode (PCN) in potato production on the Idaho economy. The primary differences between that paper and the work here are 1) the region of analysis, 2) the crops substituted for potato production, and 3) the initial shock of removing all potato acres from production.

Industry Descriptions for Model Development

In order to assess the impacts of a water shortage in the Odessa Sub-area, we employ the use of Economic Modeling Specialists International’s (EMSI) Input-Ouput (I-O) Model.[6] The value of I-O models is they track financial interactions between industries. I-O models are generally based on the national accounts originally developed by Simon Kuznets. Wassily Leontief developed the initial I-O model in 1936, winning the Nobel Prize for his work in 1973.

The system of I-O accounts represents an economist’s version of double-entry bookkeeping for industries. Figure 3 shows a simplified version of an I-O matrix with only a hand full of industries.

		Producers as Consumers						Final Demand			
		Agric.	Min.	Const.	Manuf.	Services	Other	Households	Investment	Government	Net exports
Producers	Agric.										
	Min.										
	Const.										
	Manuf.										
	Services										
	Other										
Value Added	Labor							Gross Domestic Product			
	Returns to Capital										
	Taxes										

Figure 3. Aggregated Form Input-Output Matrix

Reading down a column in Figure 3 reveals the inputs a specific industry buys to produce their output. If we look at the Agriculture column, farm businesses, for example, may buy seed from within their own sector, fertilizer and farm equipment from the manufacturing sector, and legal and accounting services from the service sector. Payments to their employees are captured

[6] The Emsi I-O model technically is a social accounting model (SAM) that includes inter-institutional relationships. I-O and SAM models are referred to interchangeably and most models today fall into the SAM categories, but the old nomenclature has persisted.

in the “Labor” row. Farms themselves receive returns to the capital that they own and pay taxes to the government.

Reading across a row reveals where an industry’s income originates. Staying with the agricultural industry, crop producers may sell seed to others in the agricultural sector, they may sell their crops to processing plants in the manufacturing sector, or they may even sell directly to consumers. As a result, a portion of each household’s expenditures in a region will go to buying agricultural goods. In addition, the government may purchase agricultural goods as well. Lastly, the agricultural industry may sell its output abroad via the “Net Exports” column.

Summing all of the labor, capital, and tax payments for all industries gives the sum of all value-added activity in a particular region and will equal the Gross Domestic Product (GDP) of the region. Similarly, summing all of the expenditures of households, government, investment, and net exports also yields the GDP of the region. These two methods of calculating GDP are known as the Income and Expenditure Approaches, respectively, and represent a check for ensuring all accounts balance. The I-O system allows us to trace the dollars through the economy and calculate multiplier effects.

<u>The I-O Model</u>

Let X equal sales within some region. Y equals exogenous demand (exports from the region) and A equals the shares of intermediate outlays.[7] Figure 3 can be mathematically represented in standard matrix notation similar to equation 2:

(2) $$\boldsymbol{XX = AAXX + YY}$$

Equation 2 simply states that total sales, *X*, is equal to the shares of sales locally, *AX*, plus sales outside of the local economy, *Y*. By solving equation 2 for *X*, we derive the Leontief multiplier matrix, $(II - AA)^{-1}$.

Total sales equal the multiplier matrix times exports, equation 3.

(3)
$$XX - AAXX = YY$$
$$(II - AA)XX = YY$$
$$XX = (II - AA)^{-1}YY$$

By calculating the change in exports and multiplying it by the multiplier matrix we are able to determine the total change in regional sales and value-added activity resulting from a shock to the regional economy.

<u>DATA</u>

The data described below represents the primary inputs to the modeling process. In order to conduct impact analyses presented here, it is necessary to look at growers and processors from an industry wide perspective. However, potato growers and processing do not have unique industry

[7] Each element of the A matrix is calculated as $aa_{iiii} = \frac{zz_{iiii}}{xx_{ii}}$, where zz_{iiii} is the element from figure 3 i^{th} row and j^{th} column, and xx_{ii} is the total sales of the j^{th} industry. The share of industry *j's* purchases from industry *i* is represented by aa_{0000}.

production functions in the Bureau of Economic Analysis (BEA) Input-Output (I-O) accounts, nor in the Emsi modeling software.[8]

Nonetheless, we need to isolate the average production technology for both the growers and processors in order to create unique production functions that can then be incorporated into the social accounting framework. This also allows for isolation of the broad expenditure patterns of each new "industry" and more closely tracks money as it flows through the economy.

This is done by converting expenditure data into input-output accounts that map spending categories to industry accounts.[9] Once properly mapped, the data are converted from purchaser prices to producer prices using a margining technique. Lastly, we rid the accounts of imports and scale them to the regional level. Full detail of this process can be found in Willis and Holland (1997).

One final note is that because the I-O model is linear, using Leontief production functions, the multipliers are not scale dependent. This means that, to the degree water curtailments and potato exports are linearly related, our results can be scaled up or down proportional to the level of curtailment. This is true of wheat production as well since it is likely the only dryland alternative.

The Direct Value of Potato Production

The standard USDA measure for reporting potato yields and prices are in cwt. Yields and prices in the following budgets are calculated on a tons per acre basis. However, it is the relative spending that is of primary importance in generating the production functions for the I-O accounts.

The five-year weighted average yield for the four-county region is 635 cwt/acre.[10] If the entire 26,519 acres currently in potato production within the Odessa Sub-area are lost, then the total output reduction of potatoes is 16,839,565 cwt. Assuming an 8% tare and shrink and average price of $7.70 per cwt, there would be a direct loss in output of $119.35 million.

It is assumed that the 26,519 acres of potato production in the sub-area would be put into dryland wheat production if irrigation water were lost. Assuming 41.4 BU/Acre and $4.20 per bushel for wheat,[11] there would be a gain of $4.62 million in crop production. The negative $119.3 million and the positive $4.62 million need to be entered simultaneously to determine the net effects of a loss in available irrigation water. Farmers in this region can only use a summer-fallow, dry-land wheat rotation so the impacts shown here will not apply to fallowed years. However, impact analysis is done on a one-year basis rather than averaging over several years. The results shown below compare one production year of potatoes vs. one production year of wheat.

Potato Processing

Frozen Potato Processing is contained in NAICS 311411- Frozen fruit, Juice, and Vegetable Manufacturing: This U.S. industry comprises businesses primarily engaged in manufacturing frozen fruits; frozen vegetables; and frozen fruit juices, ades, drinks, cocktail mixes and

[8] A complete documentation of the Emsi Model is available at https://www.economicmodeling.com/wp-content/uploads/EMSI_I-O_Documentation_Final_v3.pdf

[9] The Emsi SAM 2017.1 data, the most recent available at the time, was used to conduct the analysis.

[10] Yields by county were collected and weighted by acres in production for each county.

[11] Even though this analysis is forecasting impacts 2014 acreage, current yield, and prices were used to ensure consistency across data collection periods. Sensitivity analysis on yields and prices are available from the authors.

concentrates. A careful study of this industry in the NAICS manual reveals that it includes frozen French fries and other frozen vegetable processing.

An unpublished 2016 report by Galinato and Tozer showed that each dollar of raw potatoes purchased by frozen potato processors results in $3.08 worth of output. Thus, the $119.3 million in sales from local potato growers to local processors would translate into $367.5 million in frozen potato products. We assume that all of this output is exported out of the four-county area.

One of the competitive advantages of the region is that the potatoes grown in the Sub-area are of a higher quality, allowing them to be stored longer than potatoes grown elsewhere in the Basin. The longevity of these potatoes allows processors to sustain output year-round by processing potatoes grown in lighter soils first and potatoes from the Sub-area later in the year.

Note, we are assuming that processors do not completely shut down, they merely reduce their output because they are no longer able to supplement their raw potato inputs from local sources. We are only losing the processing of locally grown potatoes. An alternative assumption would be that all potato processing in the four-county region is lost. Under this more extreme case, the entire $1.52 billion in frozen potato manufacturing disappears. However, only about 20% of total potato processing in the four counties comes from the Odessa Sub-area. Thus, it is likely that the processors would be able to cover those losses through increased imports of potatoes from elsewhere in the CBP or even Oregon.

Transportation and Wholesale Trade

A point of deviation between this study and the previous Bhattacharjee and Holland study is that we do not include the forward-linked transportation and wholesale trade to the potato producing sector. Those losses primarily stem from the backward-linked effects from reductions in potato processing and are therefore claimed under the processing reduction scenario.

There are forward-linked transportation and wholesale trade revenues that are lost from the reduction in frozen potato processing as well. Those forward linked effects were estimated at a total of $54.74 million in rail and trucking transportation services and $30.13 million in wholesale trade services. Once these figures are multiplied by the regional purchase coefficient, the portion of those dollars going to local purchases, they become $25.1 million and $2.3 million, respectively. Thus, in the scenario where we reduce processor output, the total shock to the economy will be a reduction of $394.84 million.

Odessa Sub-area Potato Production & Processing Impacts

In this section we discuss three different scenarios and outline the changes in economic activity and employment from two specific scenarios. In a regional economy, production loss has two major impacts. The first loss results from decreased purchases of intermediate inputs to the production process. This might be reductions in fertilizer, diesel purchases, etc. At the same time, the industry loses payment to the factor inputs of labor and capital, sometimes referred to as "value-added" sectors. In our case, value-added impacts are comprised of four factors which are taxes on production and imports (TOPI), property incomes (capital payments), proprietary income, and employee compensation (labor payments). Under the above circumstances, the regional economic impact mainly consists of two major effects – direct and multiplier.

Direct effects: the changes in economic activity that takes place in the directly affected industry. For our case, this involves the impacts on the potato industry.

Multiplier effects: these changes in economic activity emanate from the subsequent ripple effect of changes in directly affected industry spending. There are two types of secondary effects – indirect and induced.

> *Indirect effects* are the changes in economic activity within the region connected through "backward-links" to the industry of concern. These "backward-linked" industries are those who supply goods and services to the industry of interest. For example, the decreased sales of the fertilizer industry or the drop in agricultural services resulting from decreased production in the potato industry.
>
> *Induced effects* reflect the change in economic activity resulting from reductions in employees' household consumption stemming from the industry of interest. For example, employees in the potato growing industry, and the supporting industries, may go out to eat less or curtail their other purchases because their income has gone down.

Scenario 1: Replacement of Local Potato Production

A scenario was proposed by Bhattacharjee and Holland where potato production in the Odessa Sub-area was eliminated but production in the remainder of the four-county region offset those losses. So, the net change in potato production for the four-county economy was unchanged, resulting in zero economic impacts (see page 23 of their report).

In order for this scenario to be modeled correctly the acres taken out of potato production in the Sub-area should be replaced with wheat or some other dryland crop. In order for potato production in the four counties to remain unchanged additional potatoes will need to be grown outside of the Sub-area. To achieve this, conservation land outside of the sub-area will have to be put into potato production or some other crop must be taken out of production to make room for potatoes. In either case, if it is more valuable to grow potatoes on that land than to use it for its current purpose, then why hasn't the farmer already converted it to potato crops?[12] If irrigation stops, this scenario would be extremely unlikely to occur. As such, we do not review this outcome. The following two scenarios provide what we investigate as the lower and upper bounds of changes in economic activity in the four counties.

Scenario 2: Loss of Local Potato Production

In this scenario we remove the potato production in the Sub-area and analyze the backward-linked losses that result as local farm revenues fall. Notably, since nearly all of the potato production in the region is sold to local processors, we are not reducing regional exports. This scenario assumes processors continue to operate at their normal levels by importing more potatoes from non-local sources. These increased leakages from importation are captured through the changing of the regional purchase coefficients and reductions in production. The type of impacts we are measuring in this scenario do not alter final demand. We are reducing intermediate demand resulting in contributions from "import-substitution," local potatoes being a substitute for non-local imports.

A reduction in potato production occurs simultaneously with an increase in wheat production under the assumption that the farmers and landowners will not opt to let their land sit idle. As most wheat is exported, this component of the analysis reflects the traditional "export base" contribution. By running both the potato loss and wheat gains simultaneously we arrive at the net change in economic activity known as economic impacts. Tables 4 through 6 show these

[12] The Odessa Sub-area already has higher yields than most other acreage in the four-county area.

impacts in terms of the lost sales, value added, and income. Because sales figures reflect double counting, they should not be used in reporting impact measures. We include the changes in sales purely for the sake of completeness and to understand how transaction volumes are affected.

Whereas sales impacts measure total changes in transactions the value-added impacts in Table 5 removes all double counting and reflects the unique value of the region's production. Often times value-added is referred to as Gross Regional Product (GRP). It does not include the payments to intermediate inputs of production.

Table 4: Sales Impacts from Lost Potato Production in the Odessa Sub-area ('000)

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	-$119,348	-$4,016	-$39	-$123,403
Potato Processing	$0	$0	-$12	-$12
Agriculture	$4,619	-$4,745	-$15	-$141
Forestry	$0	-$20	$0	-$20
Mining	$0	-$76	-$3	-$79
Utilities	$0	-$88	-$25	-$113
Construction	$0	-$464	-$190	-$654
Processed food	$0	-$81	-$100	-$181
Manufacturers	$0	-$1,450	-$84	-$1,534
Wholesale and retail trade	$0	-$1,465	-$927	-$2,392
Services	$0	-$3,909	-$2,035	-$5,944
Miscellaneous	$0	-$67	-$88	-$155
Institutions	$0	$0	-$1,840	-$1,840
Total	**-$114,729**	**-$16,381**	**-$5,359**	**-$136,469**

Source: Emsi 2017.1 and author's calculations

Table 5: Value-Added Impacts from Lost Potato Production in the Odessa Sub-area ('000)

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	-$29,187	-$982	-$10	-$30,179
Potato Processing	$0	$0	-$12	-$12
Agriculture	$1,130	-$3,781	-$8	-$2,659
Forestry	$0	-$16	$0	-$16
Mining	$0	-$42	-$2	-$44
Utilities	$0	-$62	-$17	-$80
Construction	$0	-$233	-$95	-$328
Processed food	$0	-$11	-$22	-$33
Manufacturers	$0	-$424	-$31	-$456
Wholesale and retail trade	$0	-$972	-$571	-$1,543
Services	$0	-$1,973	-$1,085	-$3,058
Miscellaneous	$0	-$44	-$42	-$86
Total	-$28,058	-$8,540	-$1,895	-$38,493

Source: Emsi 2017.1 and author's calculations

Table 6: Income Impacts from Lost Potato Production in the Odessa Sub-area ('000)

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	-$20,289	-$683	-$7	-$20,979
Potato Processing	$0	$0	-$12	-$12
Agriculture	$785	-$3,616	-$6	-$2,837
Forestry	$0	-$16	$0	-$16
Mining	$0	-$20	-$1	-$21
Utilities	$0	-$23	-$5	-$28
Construction	$0	-$180	-$74	-$254
Processed food	$0	-$6	-$13	-$19
Manufacturers	$0	-$189	-$16	-$205
Wholesale and retail trade	$0	-$502	-$352	-$854
Services	$0	-$1,171	-$850	-$2,021
Miscellaneous	$0	-$42	-$39	-$81
Total	-$19,504	-$6,448	-$1,374	-$27,326

Source: Emsi 2017.1 and author's calculations

Income impacts from the loss in potato production are reflected in Table 6. Income is a subset of value-added, reflecting only the payments to employee and proprietor labor, as well as the returns to capital received by owners, often called property income. The difference between income and value-added is usually just payments to government for import and business taxes.

Scenario 3: Loss of Local Potato Production & Associated Processing

This scenario provides a reasonable, long run, upper-bound of the economic losses that the four-county region might sustain if irrigation and thus potato production are lost. The assumption is that processors are unable to augment the loss in local supply through importation of potatoes from non-local sources. Processing output in this scenario is reduced by exactly the amount they typically purchase from producers in the Sub-area. Approximately 18.3% of potatoes purchased by local processors come from the Odessa Sub-area, so it is unlikely that the processors would shut down completely. Three things are occurring in this simulation,

1) Potato processors in the four-county region reduce their local purchases of potatoes (this is shown in the Indirect Effects column).

2) Potato growing in the Odessa Sub-area ceases.

3) Acres that were in potato production within the Odessa Sub-area are converted to dryland wheat production.

Tables 7 through 9 show the net changes in economic activity within the four-county region that are likely to occur if processors reduce their output from the lack of input supply. A total of over $606 million in transactions would be lost. Table 7 shows the loss in potato production as a backwards-linked effect of the processors and can be seen in the negative $119 million in the Indirect Effect column.

Table 7: Sales Impacts from Lost Potato Production and Processing ('000)

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	$0	-$119,348	-$114	-$119,461
Potato Processing	-$367,591	-$11,264	-$34	-$378,889
Agriculture	$4,619	-$19,706	-$44	-$15,131
Forestry	$0	-$3	$0	-$3
Mining	$0	-$12	-$12	-$24
Utilities	$0	-$213	-$74	-$287
Construction	$0	-$285	-$894	-$1,179
Processed food	$0	-$21,288	-$254	-$21,542
Manufacturers	$0	-$4,295	-$270	-$4,564
Wholesale and retail trade	-$2,291	-$12,179	-$2,698	-$17,168
Services	-$25,106	-$12,188	-$5,966	-$43,260
Miscellaneous	$0	-$396	-$251	-$647
Institutions	$0	$0	-$8,419	-$8,419
Total	**-$390,368**	**-$201,175**	**-$19,031**	**-$610,574**

Source: Emsi 2017.1 and author's calculations

Table 8 shows that the direct value-added lost from processing is $67.2 million. There is a gain of nearly $2 million from increased wheat production but forward-linked effects of wholesale trade and transportation services of $1.5 million and $10.1 million are lost as well. The indirect effects are substantial for the processing sector. Note that the indirect effects in the previous scenario were a small percentage of the overall impacts. This suggests that processors are making much larger regional purchases relative to the producers. Total value-added impacts are roughly -$138.2 million.

Table 8: Value-Added Impacts from Lost Potato Production and Processing ('000)

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	$0	-$29,187	-$28	-$29,215
Potato Processing	-$67,163	-$2,058	-$6	-$69,227
Agriculture	$1,130	-$5,286	-$23	-$4,179
Forestry	$0	-$2	$0	-$2
Mining	$0	-$7	-$8	-$14
Utilities	$0	-$145	-$50	-$195
Construction	$0	-$143	-$448	-$590
Processed food	$0	-$3,810	-$58	-$3,868
Manufacturers	$0	-$1,104	-$100	-$1,204
Wholesale and retail trade	-$1,523	-$8,118	-$1,663	-$11,304
Services	-$10,090	-$5,893	-$3,163	-$19,146
Miscellaneous	$0	-$230	-$120	-$350
Total	**-$77,646**	**-$55,981**	**-$5,667**	**-$139,294**

Source: Emsi 2017.1 and author's calculations

Table 9 tells mostly the same story. The income losses total -$114.1 million. Those losses are felt throughout the economy though the growers and processors feel the greatest impacts. In markets that are struggling to see job recovery, the loss of irrigation, potato production, and resulting declines in processing output could be devastating.

Table 9: Income Impacts from Lost Potato Production and Processing ('000)

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	$0	-$20,289	-$28	-$20,317
Potato Processing	-$53,752	-$1,647	-$5	-$55,404
Agriculture	$785	-$5,122	-$17	-$4,354
Forestry	$0	-$2	$0	-$2
Mining	$0	-$3	-$5	-$8
Utilities	$0	-$43	-$15	-$59
Construction	$0	-$110	-$347	-$457
Processed food	$0	-$2,932	-$33	-$2,964
Manufacturers	$0	-$784	-$53	-$837
Wholesale and retail trade	-$769	-$4,140	-$1,022	-$5,930
Services	-$8,541	-$4,276	-$2,466	-$15,284
Miscellaneous	$0	-$238	-$112	-$349
Total	**-$62,276**	**-$39,587**	**-$4,104**	**-$105,967**

Source: Emsi 2017.1 and author's calculations

Conclusions

Potential changes in economic activity need to be considered when proposed water use and curtailments are considered. The Bureau of Reclamation needs to carefully weigh the benefits and costs to the economy of any proposed irrigation infrastructure investments. Given the high yields and soil quality in the region, removing this land from potato production would likely raise commodity prices for processors and consumers without seeing increased gains to local farmers.

The four counties of Adams, Franklin, Grant, and Lincoln represent one of the most concentrated regions of potato farming in the Pacific Northwest. In terms of potato output, the region is over 130 times more concentrated than the U.S. as a whole. In 2015, the Odessa Sub-area alone produced more than 934,000 tons of potatoes and they generated over $119 million in sales. Processors converted those raw potatoes into more than $367 million worth of wholesale French fries, chips, and other potato products.

Exports of processed potatoes bring new money into the region. That new money is then spent by the processors on employee wages, utilities, and raw potatoes. Employees then spend their earnings on household goods (e.g., eating out at local restaurants, getting the oil in their car changed, buying a new home, etc.). As that money ripples through the economy, it creates additional rounds of spending and income until it finally leaks out of the region for the purchase of imports.

Table 10 shows that money brought into the economy through processed potato exports ripples through the economy longer, and has a higher multiplier effect, than the average dollar. For every dollar in processed potato exports, an additional 56 cents in local economic activity is generated, 42 cents more than the regional average.

Table 10: Four-County Regional Multipliers

	Regional Average	Potato Processing
Sales Multipliers	$1.14	$1.56
Value Added Multipliers	$1.17	$1.79
Income Multipliers	$1.13	$1.86

Source: Emsi 2017.1 and author's calculations

Future work on this issue needs to assess new sources of infrastructure investment that can mitigate farm costs for converting from groundwater to surface water. This work should focus on the breakeven price that will allow farms to convert to the more sustainable water resource and remain financially viable in the long run.

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