An Analysis of Plant-Based Diets' Impact on the U.S. Economy

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1. Introduction

Many Americans are facing a dietary reckoning, with plant-based diets having moved past "fad" status and into the mainstream. Although exact numbers are uncertain, GlobalData cites an estimated 600% increase in veganism in the United States between 2014 and 2017, with now nearly 6% of U.S. consumers claiming to be vegan. Plant-based diets are at an all-time high, with a majority of Americans reporting a willingness to eat more plant-based. (Lea, Crawford, & Worsley) Other parts of the world are following suit, with the Vegan Society stating that veganism has quadrupled in the last few years in the U.K., now up to over 1% of the population. (The Vegan Society) This may be associated with an increase in public awareness of health issues associated with meat-heavy diets, such as elevated blood pressure, diabetes, cardiovascular disease, and cancer. (Tuso et. al.) Additional considerations by the public may include livestock production's environmental impact and greenhouse gas (GHG) emissions, or even ethical dilemmas recently highlighted by expository journalism and various documentaries, some of which are accessible on various streaming platforms.

In response, various companies have formed in the past few years, such as Beyond Meat, which have attempted to address the growing and largely vacant market of meat alternatives. Lab-grown meats are on the horizon as well, and Euromonitor International's report suggests that plant-based alternative sales' growth is outpacing milk. (Euromonitor) Additionally, Chicago-based market research company SPINS reported that retail sales of plant-based milk grew to $2.4 billion, a 17% increase on the year in 2020—a figure which could potentially be much larger, considering it didn't even include e-commerce, presumably a large segment during the pandemic, or other key retailers of plant-based alternatives such as Costco and Trader Joe's. (Watson) This

paper seeks to examine what impact these shifts in consumer behavior may have on the economy. By looking at GDP and Labor data, as well as potential externalities in healthcare and the environmental sector, I hope to achieve a better understanding of the direct effect that an increase in plant-based diets may have on the economy. Existing literature suggests there may be benefits, but many studies are one dimensional, focusing specifically on healthcare or GHG externalities. In this paper, I will compile existing literature and use the last ten years of data on crop and livestock production, or "disappearance," and prices, taken primarily from the United States Department of Agriculture, to forecast the effect that an increase in plant-based diets might have. Through a linear regression, I aim to provide the most current assessment of the impact that an increase in plant-based diets could have on the economy and the agricultural sector, both now and forecasted over time.

2. Literature Review

Several papers, books, and articles have highlighted the impact that a consumer shift to plant-based eating could have on society. Many of these focus on economic externalities, such as GHG emissions and healthcare costs. A University of Oxford study sought to quantify some of these effects through region-specific global models of diet-related health risks, paired with emission data and evaluated with economic modules. They found that transitioning to more plant-based diets, ones in line with recommended dietary guidelines and adopting a reduction or elimination of meat and animal products, could decrease global mortality by up to 10%, reduce GHG emissions by up to 70% compared to reference scenarios for 2050, and total up to 31 trillion dollars in economic benefit. (Springmann et. al.) These authors acknowledged that these astounding figures

are best-case scenarios, and that transitioning might require some systemic changes, but, even within the ranges specified, the benefits from widely adopted dietary changes are overwhelmingly positive. On a smaller scale, a predictive model used in a Belgian and U.K. study found that if just 10% of the population committed to eating a Mediterranean diet, which consists of many vegetables and little red meat, societal cost savings totaled 1.55 billion Euros and 7.53 billion Pounds over the next 20 years, respectively. (Schepers & Annemans) The study concluded that an adherence to plant-based diets would have "large net economic gains for society and improved health outcomes for the population."

Americans stand to benefit greatly from a prospective change to plant-based diets, just based on sheer animal-product consumption. Artificially low prices induced by the meat & dairy industries, and lobbyist-influenced, government-led advertising campaigns have caused the American diet to be an overwhelmingly carnivorous one, with Americans consuming 0.6 pounds of meat per day on average, nearly three times more than any other country. (Simon) Hundreds of studies have been published in peer-reviewed medical journals over the past couple decades, not tied to the meat and dairy industry, that show that the more meat one consumes, the more likely one is to develop diseases such as cardiovascular disease, diabetes, and cancers—which of course carries high economic cost. Decreasing meat consumption is not just about economic savings, however, but also economic opportunity. The Plant-Based Food Association reported that plant-based foods, such as dairy and meat alternatives, generated $13.7 billion in revenue and could generate $13.3 billion in tax revenue over the next decade at current growth rates. (PBFA) This doesn't include the vast increase in crop consumption that would follow an increase in plant-based diets.

Another aspect of livestock production that is often called into question when discussing its impact is the issue of its sustainability, or lack thereof. A study conducted by World-Bank scientists in 2009 found that over *half* of GHG are produced as a by-product of livestock production. (Goodland and Anhang) Additionally, most corn production is used for animal feed (USDA), with over half of U.S. cropland used for livestock feed. (Simon) Not only would the decrease in livestock production free-up land for the cultivation of new crops or increase existing food availability by transferring feed-crop into consumer-viable food sources, but the impact of the crop land itself as it is used currently is resulting in groundwater contamination, surface water mistreatment, and ecological damage, both to species and the surrounding land. Furthermore, manure lagoons produced by factory farming destroy the surrounding land and, in one study, produced noxious fumes violating Minnesota State air-safety standards of ammonia and hydrogen peroxide for a mile and a half and up to five miles downwind, respectively. (The Des Moines Register) The lagoons themselves stew and cook up methane and hydrogen peroxide, along with other hazardous gases. (Simon) All of these factors not only depress property value in the surrounding area but produce harmful GHG emissions and render the land itself unsafe for use, whether that be real-estate, a natural ecosystem, or future cultivation.

Existing literature seems to support the idea that a shift away from a heavily carnivorous diet and towards a highly plant-based diet would be societally and economically beneficial. The main channels through which this benefit would come lie primarily in healthcare and environmental preservation. A potential hole in the literature is an analysis of what changes might need to be instituted to realize this shift in dietary habits, and what strain that might cause on demand. Due to data limitations

and the scope of this study, it may be difficult to account for these potentially systemic changes when considering the beneficial economic impact, but it will be insightful nonetheless to aggregate the most current United States Department of Agriculture data on the subject and forecast through regressions how our dietary habits might impact our economy over the next few decades.

3. Data

The bulk of the data utilized in the project was acquired from the USDA website. Time series tables were gathered for livestock and crop production and consumption estimates, as well as pricing for cattle. I aggregated quarterly data starting in 2010 for total red meat and poultry production in millions of pounds and total red meat and poultry per capita disappearance in pounds ('TotalMeatProd' and 'MeatDisPerPerson' respectively), where retail disappearance is an indicator for total meat consumption. The USDA reports that estimates for meat disappearance are pulled from the Resident Population Plus Armed Forces Overseas series conducted by the U.S. Department of Commerce, Bureau of the Census, and draws from the World Agricultural Supply and Demand Estimates. To control for variability in livestock pricing, I used the USDA estimate for national dollars per hundredweight for cutter cows, a classification for cattle of moderate flesh ('CutterPrice'). I also took the estimate for national dollars per hundredweight for choice cows ('ChoicePrice'), a classification of cows with more flesh and of better quality, to account for both cheaper and pricier meat varieties. These variables simply indicate how much meat was produced, how much was consumed per person, and roughly how much meat changed in price over the time period.

I gathered vegetable and pulse crop data for the time period divided by per capita availability, measured in pounds per person, and total production of fresh market vegetables, measured in millions of hundredweights. I avoided looking at all-encompassing agricultural and crop data because of the high quantities of crop production devoted to feed for livestock. As such, I tried to pinpoint fresh market vegetables, and among the vegetables delineated in the per capita availability data, I selected only vegetables that I presumed to be more likely to be eaten whole and less likely to be found in processed foods. This included fresh, canned, and frozen (if applicable) asparagus, snap/green beans, broccoli, cabbage, carrots, cauliflower, celery, cucumbers, lettuce, onions, peppers, tomatoes, sweet potatoes, and mushrooms. Additionally, I excluded corn as well, since the majority of corn in the United States is produced for livestock feed. (USDA ERS) The sum of the weight of these vegetables, in available pounds per person, formed the variable 'VeglbPerson'. The production of fresh market vegetables forms the variable 'VegProdFresh'.

Because there is not much reliable, large-scale data that looks at the number of people partaking in a plant-based diet, I created a variable to act as an indicator for increasing vegetable consumption relative to meat consumption. By dividing 'VeglbPerson' by 'MeatDisPerPerson' I could effectively determine the ratio of the average person's vegetable to meat consumption for the aforementioned selected vegetables. The higher this ratio, in theory, the closer the average population is to a plant-based diet. This variable is named 'VegMeatCons,' and the change of this variable by year is named 'VegMeatConsChange' which will be the main variable of interest for this study. Because I am looking at the effect that an increase in plant-based diets might have on the U.S. economy, I took quarterly real GDP data on a 2012 index of 100 from

the Bureau of Economic Analysis. To avoid falsely high correlation when conducting the regression, I calculated the percent change between quarters. This variable, 'GDP', is one of my dependent variables. I am using it as a rough indicator for economic performance and aim to see its change as per capita vegetable consumption increases relative to meat consumption.

Because GDP is so all-encompassing, however, I sought to find a more targeted indicator of economic performance that might be more directly impacted by consumer habitat regarding meat and vegetable consumption. As such, I pulled industry-specific GDP data from the Bureau of Economic Analysis that outlines farming and agriculture's contribution to the percent change in the chain-type price index for gross domestic product ('AgricGDP'). By narrowing the scope of the gross domestic product I'm looking at, I will hopefully assess more pointedly the channel through which, if at all, vegetable and meat consumption habits might have on the economy. An additional indicator I will look at to examine potential economic impact is wages. The Bureau of Labor Statistics compiles expansive national occupational employment data across a wide variety of industries. I pulled the mean hourly wage for occupations relating to agriculture and farming, including agricultural engineers, technicians, farm workers, and others, and calculated the percent change between every quarter. The percent change prevents the gradual increase from inflation to conflate the wage data, and the resulting variable is named 'AgricWage'.

I have also included demographic data, pulled from the Census Bureau datasets for the American Community Survey. This aims to control for demographic changes in the population. As reported by the USDA and the US Department of Health and Human Services' joint survey, the National Health and Nutrition Examination survey, there is

evidence that different demographic groups have different meat and vegetable consumption patterns. As such, I gathered annual data for the percent of the population that is male ('PopMale'), the percent of the population that is under 20 years old ('Pop20'), the percent between 20 and 65 ('Pop2065'), and the percent over 65 ('Pop65'). I also looked at what percentage of the population identifies as white ('PopWhite') and what percentage of the population identifies as black ('PopBlack').

Below is a table outlining a summary of statistical properties of the data:

Variable	**AgricWage**	**AgricGDP**	**VegMeatCons Change**	**TotalMeatProd**	**CutterPrice**	**ChoicePrice**
Units	Annual % Change	Annual % Change	Annual % Change	Millions of lbs.	Dollars	Dollars
Min	-0.228	-0.580	-4.896	22469	49.07	95.470
Max	1.361	0.680	11.495	27308	111.27	165.60
Std.Dev.	0.435	0.241	3.725	1225	17.05	17.10
Mean	0.576	-0.007	-0.233	24119	73.58	124.66
Median	0.669	0.020	-1.386	23671	73.16	122.30

Variable	**VegProdFresh**	**PopMale**	**Pop20**	**Pop2065**	**Pop65**	**PopWhite**	**PopBlack**
Units	Millions of cwt	Percent	Percent	Percent	Percent	Percent	Percent
Min	89.957	0.491	0.252	0.592	0.127	0.725	0.125
Max	99.910	0.492	0.273	0.600	0.156	0.742	0.127
Std.Dev.	3.000	0.000	0.007	0.003	0.009	0.006	0.001
Mean	94.386	0.492	0.262	0.597	0.141	0.735	0.126
Median	93.860	0.492	0.260	0.597	0.141	0.736	0.126

4. Methods

The primary statistical method I use for this analysis is a regression. The baseline equation, which aims to look at the impact that vegetable-to-meat consumption might have on the economy, is as follows:

$$\text{AgricGDP} = \beta_0 + \beta_1 \text{VegMeatConsChange} + \varepsilon$$

Where AgricGDP represents the dependent variable, β_0 the intercept of the equation, VegMeatConsChange the independent variable, and ε the random error term. However, as outlined above, I will look instead at AgricGDP, as well as AgricWage, in two separate regressions. Then, by including the variables to control for pricing, production, and demographic changes in the population, the regressions now look like this:

$$\text{Dependent Variable} = \beta_0 + \beta_1 \text{VegMeatConsChange} + \beta_3 \text{TotalMeatProd} + \beta_4 \text{VegProdFresh} + \beta_5 \text{CutterPrice} + \beta_6 \text{ChoicePrice} + \beta_6 \text{PopMale} + \beta_6 \text{Pop20} + \beta_6 \text{Pop2065} + \beta_6 \text{Pop65} + \beta_6 \text{PopWhite} + \beta_6 \text{PopBlack} + \varepsilon$$

Where the dependent variables for the regressions will be AgricGDP and AgricWage, respectively.

5. Results and Discussion

Dependent Variable: AgricGDP

R-Squared	Adj.R-Sqr.	Std.Err.Reg.	Std.Dep.Var.	# Fitted	# Missing	Critical t
0.279	-0.014	0.243	0.241	39	0	2.052

Variable	Coefficient	Std. Error	t-Statistic	P-value	Lower95%	Upper95%
Constant	-58.249	111.320	-0.523	0.605	-286.657	170.160
ChoicePrice	-0.006940	0.007175	-0.967	0.342	-0.022	0.007782
CutterPrice	0.005524	0.008968	0.616	0.543	-0.013	0.024
Pop20_	146.869	87.735	1.674	0.106	-33.149	326.888
Pop2065_	40.310	67.033	0.601	0.553	-97.229	177.850
Pop65_	143.338	134.021	1.070	0.294	-131.649	418.326
PopBlack	-109.689	249.355	-0.440	0.664	-621.323	401.945
PopMale	-76.780	293.812	-0.261	0.796	-679.633	526.072
PopWhite	37.943	92.150	0.412	0.684	-151.133	227.020
TotalMeatProd	0.000036	0.000138	0.260	0.797	-0.000248	0.000320
VegMeatConsChange	0.011	0.018	0.593	0.558	-0.026	0.047
VegProdFresh	-0.012	0.021	-0.584	0.564	-0.056	0.031

Dependent Variable: AgricWage

R-Squared	Adj.R-Sqr.	Std.Err.Reg.	Std.Dep.Var.	# Fitted	# Missing	Critical t
0.761	0.652	0.256	0.435	36	3	2.064

Variable	Coefficient	Std. Error	t-Statistic	P-value	Lower95%	Upper95%
Constant	496.603	118.468	4.192	0.000	252.097	741.109
ChoicePrice	-0.007051	0.008251	-0.855	0.401	-0.024	0.009978
CutterPrice	0.003005	0.010	0.291	0.774	-0.018	0.024
Pop20_	61.445	125.323	0.490	0.628	-197.209	320.100
Pop2065_	-3.374	76.418	-0.044	0.965	-161.093	154.345
Pop65_	245.278	191.914	1.278	0.213	-150.812	641.369
PopBlack	-604.667	342.746	-1.764	0.090	-1,312	102.727
PopMale	-1,203	338.480	-3.553	0.002	-1,901	-504.045
PopWhite	175.886	119.275	1.475	0.153	-70.284	422.057
TotalMeatProd	0.000020	0.000176	0.112	0.912	-0.000343	0.000383
VegMeatConsChange	-0.011	0.021	-0.534	0.598	-0.055	0.033
VegProdFresh	-0.061	0.029	-2.131	0.044	-0.120	-0.001915

After running the regressions in excel, several issues surface. The variability in the coefficients, the lack of statistical significance, the swings in standard error, and the underwhelming R-squared values indicate that the regressions, or the data available within it, don't provide much clarity with regard to the direct impact that vegetable to meat consumption ratios and changes in consumer dietary habits might have on the economy. This is not to say that there is not an effect. The choices that consumers make impact demand, and their consumption habits impact the economy. Whether we are able to see what effect that has on a macro-scale in this regression is uncertain.

The first regression suggests that an increase in the vegetable to meat consumption ratio would decrease agricultural GDP. This could be due to the sheer strength of the grasp that the meat industry has on the economy and the resulting shock that might occur if there is a drastic change in the composition of the standard American diet. Indeed, the model for agricultural wages, which shows similar trends to wages as GDP for vegetable to meat consumption ratio increases, actually shows a forecasted increase—though slight—in total meat production over the next few years. Another coefficient of note is that of the young and working-age populations. The model suggests that a shift towards a younger age-demographic would increase agricultural GDP. This may be simply because younger people tend to eat more than older populations.

This data may not be reliable however, and the p-value indicates that this does not hold statistical significance, especially given the adjusted R-squared value of 0.192. Here, I presume that lack of data is driving the inconsistencies in the analysis. This study looks at just under a decade of quarterly data, some of which is annual data subdivided into quarters. Any data examined previous to this may not see any effect due to the more recent nature of the uptick in plant-based diets. Increased awareness

regarding ethical issues in the livestock industry have been most clearly highlighted by mass-watched documentaries and reports only recently published, and farming's direct impact on the environment is coming into the mainstream as climate change becomes a more pressing issue. Additionally, there is increasing media coverage on the benefits of eating a diet filled with diverse plants and the number of diseases and illnesses now linked to the consumption of meat and animal products—many previous studies were largely funded by industries with vested interests in the increased consumption of meat and dairy. It may be more applicable to see this change over the course of the next ten, twenty, or thirty years.

Of course, there is the possibility that even given the data and accounting for any lag associated with this behavioral shift in terms of how it is represented with economic indicators, we could still see that a shift to plant-based diets would have a negative effect on the U.S. economy. As I have mentioned, there could be short term repercussions associated with a large-scale behavioral change. Industries would need to adjust as the market for dairy and meat alternatives grows, demand for produce is strained, and the meat and dairy industry begin to falter. This could be true of any major industry, but especially so for one as deeply ingrained in our economic, political, and personal spheres as the meat industry, which has penetrated our views on nutrition and shaped a culture of consumption in the U.S. Additionally, it might be that this change could simply negatively affect GDP and wages through other, less explicit channels.

Based on evidence from my literature review, however, it seems that the projected positive externalities tied to the adoption of plant-based diets would not be undermined by any short-term disruption and any costs or setbacks that ensue. This might be studied more closely in a future analysis with better data on the actual number

of plant-based diets and a more narrowed look at through what channels these diets impact the economy

With an increase in meat-substitutes and awareness of the issues highlighted above, we may see consumer habits impact the economy, for better or for worse. It is possible that a move away from meat and dairy will shock an industry that has long dominated the American diet. There may be a lag as well associated with the changes in demand and the impact it then has on the American economy. Regardless of the result, with more data over a longer period of time, results might be at the very least less nonsensical. However, given the limited scope of this study—primarily due to limited data and the implementation of variables created to replace nonexistent data (percent of the population adhering to a plant-based diet replaced by a vegetable to meat consumption ratio, for example) resulting in a lot of noise—the current regression analysis seems to be unfruitful. It may be more useful, then, to focus on projected externalities, which may be easier to calculate and have demonstrated that there would be benefits to an increase in plant-based diets, at least in some industries like healthcare, or over the long-run thanks to an improved atmospheric composition due to the decrease in methane and other harmful greenhouse gasses produced by the meat and dairy industry.

6. Conclusion

Plant-based diets aside, it seems evident from health-care costs alone that the health of the American people is hurting its economy. There seems to be potential value inherent in improved education surrounding nutrition to account for gaps in the public understanding of health and what is healthy. Additional possible corrective behavior might include Pigouvian meat taxes aimed at correcting behavior and over-consumption of meat—at least per existing and arguably outdated health guidelines. However, this might not highlight a direct impact on GDP or wages. Future studies will have to seek out clearer data and parcel through the noise of the data regarding the economy at large to look at what macro-level effects might be seen from such a consumer change.

It seems, though, that change is coming. As alternative meat and dairy prices rise and consumers become more aware of meat-related issues both within the industry—in terms of livestock treatment and environmental implications—and with our health, we will see consumer behavior change, which will undoubtedly affect the economy. While actual non-externality-based numerical projections remain unclear, it will be interesting to keep track of any potential effects caused by a change in the landscape of the American food industry.

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