Curing Citrus Greening: Implications along the Supply Chain

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Introduction

- The United States is a leading producer of citrus behind Brazil and China.
- The industry is facing an existential threat, Huanglongbing (HLB), a bacterial disease commonly known as citrus greening.
- HLB imposes economic costs to commercial citrus growers in three ways (i) increases the mortality rate of citrus trees (ii) reduces the marketability of yield (iii) increases production costs due to disease management practices.

Motivation

- The orange yield fell from nearly 64%, from 20 short tons per acre in 2003/04 to less than 10 tons per acre in 2020/21, and bearing acreage was down 40% compared to twenty years ago (USDA-ERS 2021, Fruits and Tree Nuts Yearbook Tables).
- Nearly $1 billion has been invested in research and other efforts to address HLB (Thompson 2021), but there is yet no known cure.
- We envision that citrus farmers will adopt the new technology once a cure is found. But the total welfare gains from the technology adoption will be spread and dissipated across different participants along the supply chain
- To isolate the welfare improvement to the growers, one needs to identify the distribution of the welfare gain among different participants along the supply chain (growers, packers, juice processors, and consumers).

Objective

- Dissect the welfare impact of positive technology shock on the market outcomes and welfare of heterogenous agents along the vertical US orange supply chain.
- The aggregate welfare effect will inform the US government and funding agencies about the level of investments that may be justified in finding a cure for citrus greening and prioritize future research.
- Welfare impact on different agents along the supply chain will inform stakeholders, especially the growers – the most likely adopters of the technology

Supply Response of Perennial Crop

We rely on the theoretical framework of French and Matthews (1971) to model the supply response of perennial crop

The change in bearing acreage can be written as: $\Delta B_t = f(\Delta p^e, \overline{B_{t-r}}, \overline{y_{t-s}}, t, HLB)$

Where, Δp^e is the change in *j* year moving average of real producer price of orange, $\overline{B_{t-r}}$ is the *k* year moving average of bearing acres, $\overline{y_{t-s}}$ is *m* year moving average of yields, *t* denotes time, and *HLB* is an indicator variable that is equal to "1" from 2005 onwards and "0" otherwise. Here *j*, *k*, *m*, *r*, and *s* will be determined econometrically. We use data from season 1980/91 to 2021/22.

Variables $\overline{B_{t-r}}$, $\overline{y_{t-s}}$ and Δp^e are collected from USDA-ERS, Fruit and Tree Nuts Yearbook Tables and FDOC, Citrus Reference Book.

The change in bearing acreage estimation:

$$\Delta B_t = \underset{(21.90)}{76.75^{***}} + \underset{(3.49)}{8.03^{**}}\Delta p^e - \underset{(0.03)}{0.16^{***}}\overline{B_{t-2}} + \underset{(1.85)}{3.49^{*}}\overline{y_{t-2}} - \underset{(5.15)}{35.77^{***}}HLB$$

Intertemporal Equilibrium Displacement Model (EDM)

We adopt an intertemporal equilibrium displacement model with intermediaries based on earlier works of Jiang, Cassey, and Marsh (2017) and Tozer and Marsh (2018). We need an intertemporal model because of the perennial nature of the citrus crop.

Farm-level Supply $FS_{t+1} = S_{t+1} y_{t+1} B_{t+1} = S_{t+1}(1+g) y_t (\Delta B_t + B_t)$,

where *FS* is farm supply, S_{t+1} is an exogenous supply shock, *y* is yield, *B* is bearing acres, and g is the growth rate of yield.

- Farm supply of fresh oranges: $FS_{f,t} = FS_{f,t}(p^F_{f,t}, FS_t)$, where *f* denotes fresh and superscript *F* denotes farm. A market clearing condition is used to allocate the remaining fruit to the processed market: $FS_{p,t} = FS_t - FS_{f,t}$, where subscript *p* denotes processed.

Retail Demand $QD_i = pop.\, f_i^D(p_f^r, p_p^r, I, z)$,

where *pop* is US population, superscript *r* denotes retail, *I* denotes income, and *z* is a vector of demand shifters.

International Trade

- The export demand function $E_i = f_i^{Ex}(p_i^W - t_{x,i})$, where p_i^W is the wholesale price of commodity *i* and $t_{x,i}$ is the export cost
- The import supply function $M_i = f_i^{Im}(p_i^W - t_{m,i})$, where $t_{m,i}$ is the import cost
- Domestic retail supply $QS_i = FS_i + M_i - E_i$

Wholesale-Level Intermediaries

- The farm-wholesale price relationship $p_i^F = p_i^W - MM_i^F$, where MM_i^F is the markup between farm and wholesale level.
- The retail-wholesale price relationship $p_i^R = p_i^W + MM_i^R$, where MM_i^R is the markup between the wholesale level and retail.
- The market clearing condition $QD_i + E_i = FS_i + M_i$

Technology Shock Scenario

1) We model a positive technology shock by switching the *HLB* indicator in the econometric model off, which in combination with historical data is used to predict the change in bearing acreage.
2) The change in bearing acreage causes an increase in farm supply.
3) Increase in farm supply passes through the equilibrium displacement model to give us new values of endogenous variables.
4) Values of relevant endogenous variables are fed back into the bearing acreage equation, and the process repeats itself for 60 years (2023-2083)

Data for EDM

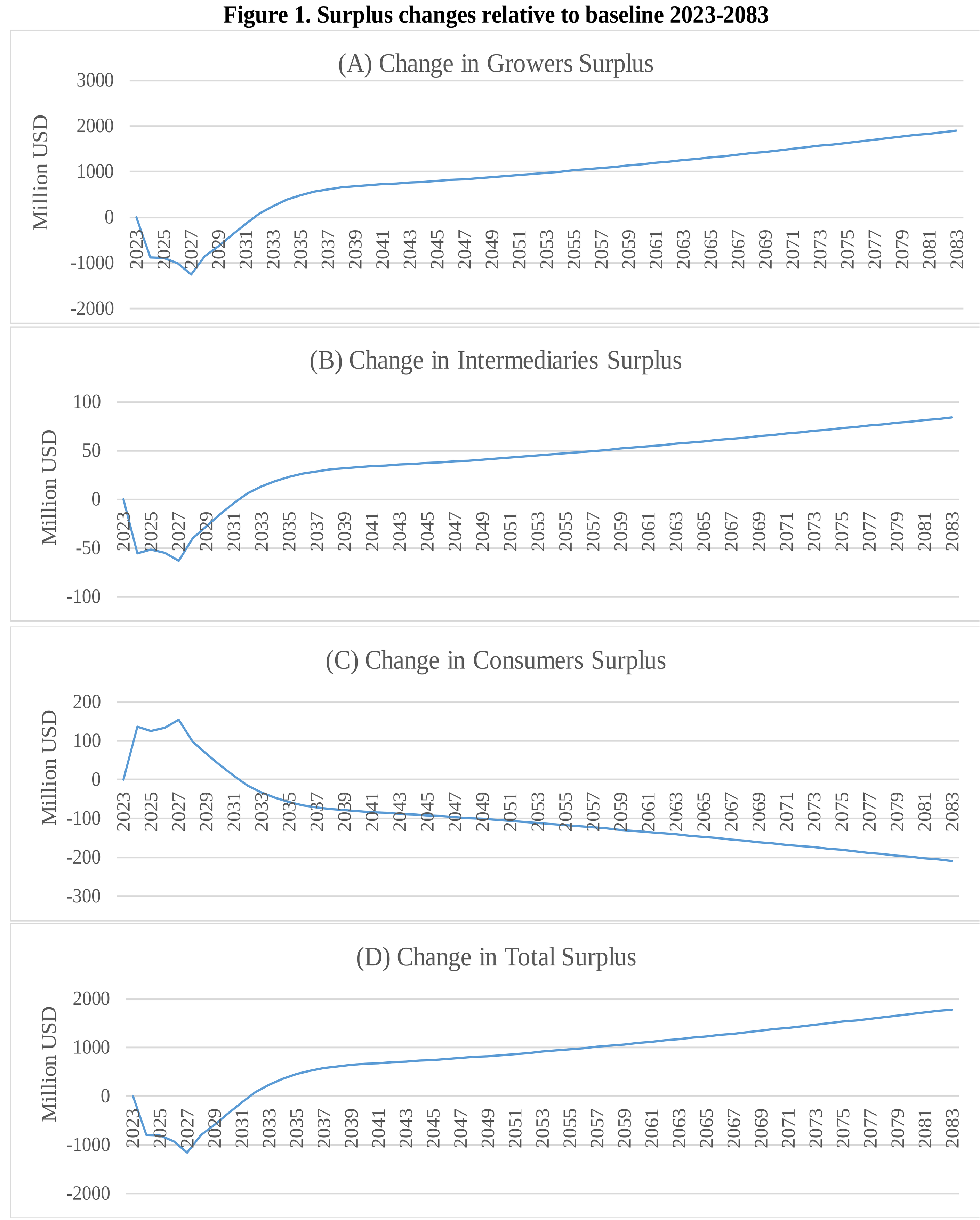
- **Baseline:** We assume 2022 as the baseline for the EDM. The US domestic production volumes and prices for fresh and processed were collected from USDA-ERS and FDOC. Trade volumes and prices were obtained from USDA-FAS and FDOC. As the market clears at the wholesale level, we based our wholesale prices as weighted averages of the import and export prices. Retail prices were obtained from BLS. As we are dealing with both fresh and processed fruit along the supply chain, we converted all fruit quantities into Single Strength Equivalent (SSE) gallons.
- **Elasticities:** We assumed the total production elasticity of allocation towards the fresh market based on fresh orange proportion in total orange production. The export elasticity for fresh orange , import elasticity of for processed orange, retail price elasticity for fresh orange, retail price elasticity for processed orange, income elasticity for processed and fresh orange are all borrowed from the extant literature. We imputed cross-price elasticities by imposing homogeneity of degree zero in prices and income for the Marshallian demand.
- **Exogenous demand shifters** include US population growth rate, based on the 2019-2022 period, and US GDP growth rate, based on 2017-2020 period, both collected from Macrotrends.net (2023). Annual yield growth rate (g) is computed based on a three-year moving average yield during the pre-HLB era (1981-2004).

Results

Table 1. Net Present Value of surplus changes (2023-2083) in million USD

	Growers	Intermediaries	Consumers	Society
NPV of the surplus change	5,311	215	-544	4,982

Figure 1. Surplus changes relative to baseline 2023-2083



Conclusions

- Due to a cure for HLB, growers gain a significant amount of producer surplus, intermediaries experience moderate gains, and consumers face a loss in consumer surplus. However, when considering the overall societal perspective, the total surplus demonstrates a net gain.
- This study emphasizes the need for strategic investments in finding a cure for HLB and implementing technologies to mitigate its impact. That could yield substantial benefits for growers and safeguard the citrus industry's long-term viability .

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