Economic Aspects of Maui County's Seed Industry

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Executive Summary

- This report is motivated by a Maui County ballot initiative to shut down maize (corn) agronomic research and seed production by banning cultivation of *transgenically*-modified crops, such as Rainbow papaya, for at least two years while the county studies impacts.

- Essentially all modern crops are genetically modified organisms, like the popular low-acid Maui Gold pineapple, Maui sugarcane, and modern maize (corn) varieties.

- Maize in Hawaii is known back to the missionary era, limited to highland cultivation in the 19th century because of tropical lowland diseases, resistance to which 20th century plant breeding mastered; today's seed industry began as winter nurseries on Molokai in the 1960s, and over 50 years it has been the fastest growing agricultural activity in the state.

- The seed industry today is Hawaii's largest single agricultural activity, more than one-third of the statewide total, comprising about one-half billion dollars in total economic impact and at least 2,800 jobs statewide including multiplier effects.

- Hawaii seed industry receipts comprised 23 percent of the market value of crop and livestock products sold in the last agriculture census, but only 10 percent of agricultural land acreage exposed to agricultural chemicals (23 percent of insecticide exposure, 8 percent of herbicide exposure): the seed industry is a *less* significant source of pesticide exposure than other agriculture sources of exposure, which are less significant than *urban* sources of exposure.

- The seed industry is as much as one-quarter of all Maui County agricultural activity, it generates $84 million in economic output and more than 950 jobs including multiplier effects, county-wide; on Molokai, where the seed industry comprises ten percent of all private sector jobs, it is the most significant private industry activity besides tourism.

- As with all farming, Maui County's seed industry after fifty years today is woven into the economic fabric of the community: annually it is a source of more than 3,500 volunteer hours, more than $20,000 in scholarships in life sciences and more than $35,000 in donations for science, technology, engineering, and mathematics (STEM) education in local schools.

- Hawaii seed industry activity—forty percent of which is research and development activity, sixty percent of which is seed production—plays a pivotal role in global knowledge capital-formation, yielding dynamic gains in productivity and living standards from the creation of ideas and their dissemination through the maize genome.

Introduction

A ballot initiative in Maui County intended for consideration in November 2014 seeks to shut down operations of seed companies engaged in agronomic research and development in the maize (corn) genome. Specifically, it seeks a moratorium on all farming in Maui County involving "genetically engineered" organisms (what the initiative calls GMO) for at least two years while impacts are studied.[1] Maui County currently is free to study genetic modification as a crop improvement practice and the cultivation of genetically-modified organisms generally *without* a moratorium. Most of what Maui County could learn is readily available in the scientific literature. Yet, the proposed GMO ban is now on the ballot.

Such a farming shutdown would throw out of work hundreds of Maui residents. The seed industry alone provides employment for nearly 650 skilled biotech workers in Maui County ranging from scientists to seasonal farm labor. Hundreds more work in supplier industries, or depend on the seed industry's other economic impacts. A shutdown would forego nearly $85 million in annual economic output in Maui County when including multiplier effects. Seed farming is Maui's second largest agricultural activity after sugarcane cultivation, and the largest activity on Molokai. It is too important to Maui County's economy to be placed on hiatus.

A ban on cultivation of genetically engineered organisms of *all* kinds also would ban commercially successful crop varieties such as Rainbow papaya. Other crops being contemplated by commercial agronomic research companies that could significantly improve health and welfare in the future also would be banned by the initiative. Pre-emption would include even those crops we don't know today that might be important tomorrow, foreclosing options rather than keeping them open. The initiative would extend beyond corn seed to all foods and agricultural activities such as floriculture and nursery products, to the development of bio-fuels, to materials sciences, to pharmaceuticals for the treatment of emerging diseases—just as experimental *Ebola* anti-viral drugs currently are being grown on tobacco. Such a ban would halt work not only on existing diseases but in anticipation of diseases that have yet to evolve. A ban also would impair work on the preservation of endangered and endemic species in Hawaii that are threatened by alien pathogens and by aggressively competitive, invasive species. A Maui County genetic engineering ban would close the door on a wide range of beneficial scientific pursuits as well as commercial applications.

This report analyzes economic aspects of Maui County's corn seed industry, but the wider agricultural implications of a genetic engineering ban are at stake. Keeping Maui County's scientific options open and preserving employment opportunity for hundreds of highly-skilled and well-paid workers in the county's largest agricultural activity besides sugarcane production is too important to allow fear and misinformation to cause so great an economic disruption. Agriculture generally in Maui County should be allowed to flourish without banning modern techniques. Fifty years of corn breeding and of the corn seed industry in Maui County, including decades with transgenic techniques and more than a century of active genetic modification in agriculture generally, have yielded no evidence of harm to humans or the environment. This report documents the seed industry's economic benefits to Maui, Molokai and the state of Hawaii.

Background on corn in Hawaii

Corn (*Zea mays*), in English-speaking countries, or maize from the Spanish *maiz*, is a member of the grass family with evolutionary links to *teosinte* through mutation, natural selection, and hybridization. Both originate in present-day Mexico, Guatemala, and Nicaragua. Original wild forms have long been extinct.[2] Modern DNA methods comparing *teosinte* and maize genetic profiles can calculate genetic distance between the two grass strains. These techniques suggest that domestication of corn occurred about 9,000 years ago in southern Mexico. Archaeological findings of maize residue on stone milling tools, from carbon-dated geologic layers, confirm this time-line. Prehistoric farmers spent centuries—millennia—selecting strains whose genetic characteristics allowed them to free kernels from their tough cases, and to identify more nutritious kernels and those with more kernel rows.

Pre-Columbian Mesoamerican peoples, such as the Mayans, had developed highly-sophisticated, corn-based cultures in the pre-European contact era. One of the primitive, cultivated varieties of corn was Nal-Tel, the staple for Mayan civilization in today's Guatemalan lowlands and the Yucatan Peninsula. By the time of Columbus, in the late-15th century, corn was the most important cultivated plant in the Americas. Its range extended from the St. Lawrence River valley to the Andes. Columbus is believed to have returned to Spain with corn on his earliest voyages. As with many crops that originated in the Americas like potatoes, tomatoes, chilies and other peppers, corn had dispersed by the late 16th century around the world as far as the Philippines and East Asia.

Corn came to Hawaii shortly after Captain Cook's discovery voyage. Early Hawaii missionaries gardened corn (noted in Damon family letters).[3] Nineteenth century Hawaii yields were disappointing because of insects and diseases. The Royal Hawaiian Agricultural Society encouraged research on "Indian" corn in the 1850s.[4] Field corn was grown as a livestock feed crop on Kauai as early as 1853. It was more successfully cultivated in cooler uplands of Maui and Hawaii Island. Corn diseases like the mosaic virus and its leaf hopper insect vector do not tolerate winter cold in such highlands. By the end of the 19th century 7,000 acres of corn were grown in Kula and in Parker Ranch country. Efforts to identify virus-resistant corn varieties beginning in the 19-teens were largely unsuccessful.[5] Although corn acreage in Hawaii peaked in 1919-20 at 10,000 acres, buoyed by World War I, efforts to find virus resistance were abandoned in 1928. Corn disappeared as a lowland crop in Hawaii, reduced to about 1,700 upland acres. Dr. Albert Mangelsdorf of the Hawaii Sugar Planters' Association introduced breeding for maize mosaic virus resistance in Hawaii during the 1940s.

Tropical breeding of corn varieties became a renewed focus of agronomic research at the University of Hawaii College of Tropical Agriculture during the early-1960s. Cooperative trials between the UH and several U.S. midwest organizations (including Cornnuts, Inc. and Illinois Foundation Seeds) first sought to evaluate mainland varieties during the winter of 1964-1965. Within a few years these collaborations were formalized through the Molokai Seed Service. Molokai winter nurseries rapidly attracted major U.S. seed companies such as Pioneer, Trojan, and Northrup King, as well as some local Hawaii agribusiness interests. By the late-1960s more than 500 acres of seed corn were being cultivated.[6] It spread to Kauai, Oahu, and Maui Island.

Only recently, during the 2012-2013 winter crop season, did Hawaii corn seed crop acreage return to 9,000 acres (as in the late-19th century), from which over 7,000 acres were harvested. This marked a dramatic increase from the 170 acres—on Molokai—of the seed industry's 1967-1968 winter season, the first with data compiled by the Hawaii Department of Agriculture. Hawaii's seed industry has grown steadily since those humble origins on Molokai in the 1960s. Statewide seed industry acreage has grown at an 8.6 percent annual average rate since 1967. Seed outshipments grew at an 11.8 percent annual average rate over those 45-50 years. The value of economic activity in the seed industry grew at a 15.1 percent average annual rate from 1968-2013. No other agricultural activity—possibly no other economic activity of *any* kind in Hawaii—has grown so rapidly and so steadily for as many decades since the mid-20th century.

The modern seed industry in Hawaii is a leading biotech sector. It has succeeded entirely on its own without government subsidies. Throughout the seed industry's history since the 1960s, corn seed has comprised at least 95 percent of seed production. Late-20th century decline of Hawaii plantation crops, sugarcane and pineapple, released thousands of acres of prime agricultural land along with agricultural infrastructure that could be redeployed in the fast-growing seed industry. This handover of agricultural lands to the seed industry tempered some of the untoward employment and business impacts associated with the plantations' demise.

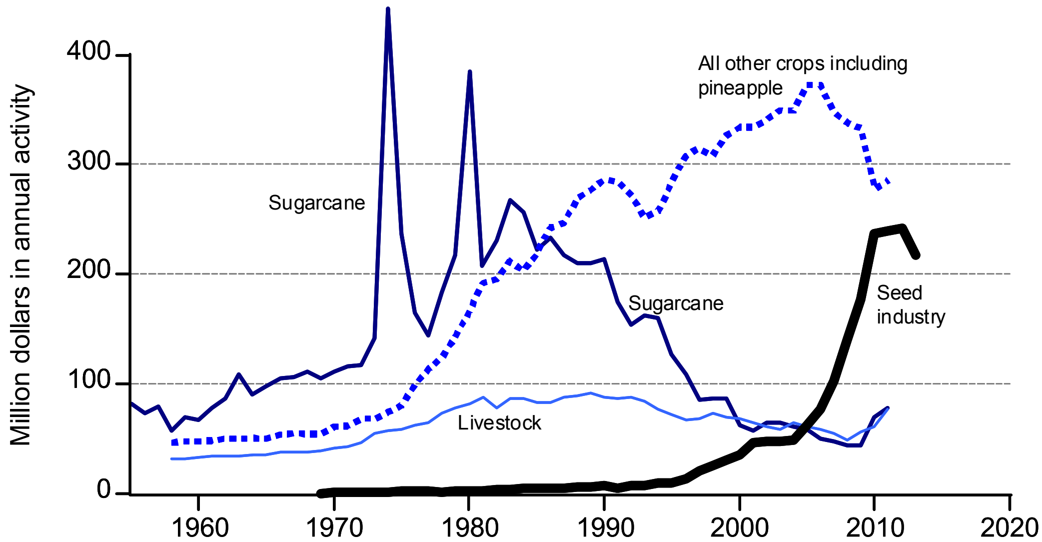
By exploiting winter, when U.S. midwestern seed companies were unable to carry on their plant breeding and seed production activities on the mainland, Hawaii's seed industry capitalized on a tropical comparative advantage. Protections of U.S. intellectual property law gave Hawaii's status as the Fiftieth State an advantage among tropical locales. Ample nonstop commercial aviation connections supported production of a high value-to-weight-ratio exportable. Finally, a unique technical and scientific human capital endowment in Hawaii supported the seed industry and, in turn, has been further nurtured by the industry. The importance to the Hawaii seed industry's emergence of decades of ongoing tropical plant breeding at the University of Hawaii College of Tropical Agriculture, Pineapple Research Institute, Hawaii Sugar Planters Association, and Hawaii Agricultural Research Corporation cannot be overemphasized.

Statewide Hawaii seed industry economic impacts

Hawaii's seed industry has rapidly grown, over a half century, to become the state's single largest agricultural activity (see Figure 1 and Figure 3).[7] Comprising more than one-third of all agricultural activity in the islands, Hawaii's seed industry is more important to agriculture than tourism *and* federal defense, combined, are to the overall Hawaii economy.

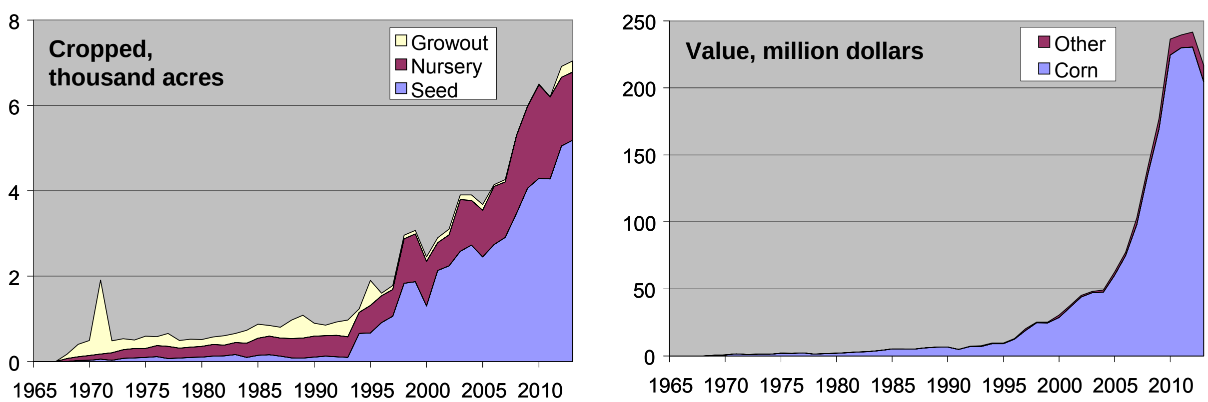
Hawaii's seed industry is a farming activity like any other. In the most recent *2012 Census of Agriculture* (May 2014), 367,142 bushels of corn for grain were harvested in 2012 on 15 farms in Hawaii comprising 5,196 cropped acres, for seed yields of 71 bushels per acre. This yield is up from the 2007 census, when 124,878 thousand bushels on 14 farms comprising 3,115 cropped acres in Hawaii yielded 40 bushels of seed per acre. (U.S. corn growers in 2014 will yield a record 171.1 bushels of grain per acre, 93 percent of it biotech. For comparison, U.S. organic corn (grain) yields are approximately 120 bushels per acre, on 0.16 percent of 83.8 million acres of total U.S. corn (grain) farm acreage.[8])

Figure 1
A half century of Hawaii agricultural activity



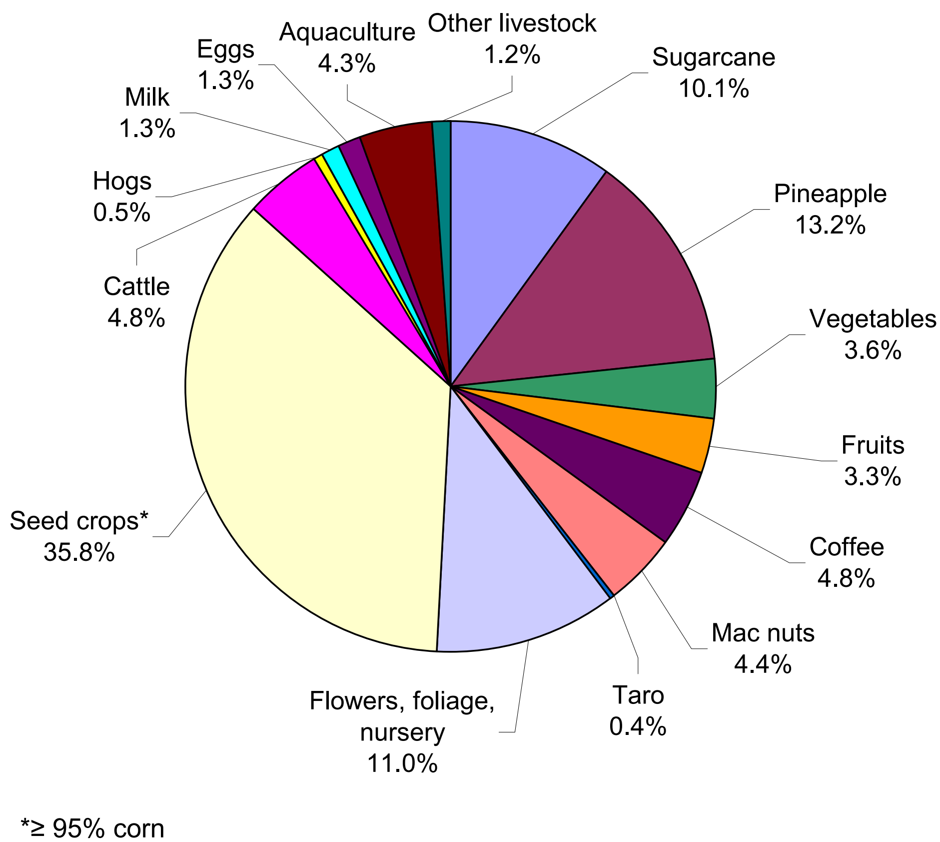
Sources: Hawaii Agricultural Statistical Service (http://www.nass.usda.gov/Statistics_by_State/Hawaii/index.asp#.html), Hawaii DBEDT (http://dbedt.hawaii.gov/economic/databook/), USDA National Agricultural Statistics Service (April 11, 2014), Hawaii Seed Crops Report (http://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Sugarcane_and_Specialty_Crops/2014HawaiiSeedCrops.pdf).

Figure 2
Hawaii seed industry acreage and outlays



Sources: Hawaii Agricultural Statistical Service (http://www.nass.usda.gov/Statistics_by_State/Hawaii/index.asp#.html), USDA NASS in cooperation with Hawaii Department of Agriculture *Pacific Region—Hawaii Seed Crops* (various), *Statistics of Hawaiian Agriculture* (various), Hawaii DBEDT *State of Hawaii Data Book* (various), Robert C. Schmitt (1976), *Historical Statistics of Hawaii*, University of Hawaii Press; data re-aggregations by TZ Economics

Figure 3
Distribution of Hawaii statewide crop, livestock and aquaculture sales and activity; $689.6 million in 2010



Sources: USDA National Agricultural Statistical Service in cooperation with Hawaii Department of Agriculture, *Hawaii Annual Statistical Bulletin* (*Statistics of Hawaii Agriculture*) 2010 (**http://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Annual_Statistical_Bulletin/index.asp**)

As illustrated in Figure 2, Hawaii seed industry acreage exploded in the 1990s after the closure of sugar and pineapple plantations. Seed industry farm acreage statewide rose from less than 1,000 acres before the 1990s to more than 7,000 acres in the most recent winter crop season. Seed outshipments rose from less than 1 million pounds annually before the 1990s, to more than 12 million pounds in the most recent season. The total value of seed industry activities, including agronomic research, rose from less than $7 million annually before the1990s to as much as $240 million in recent crop seasons.

The state's input-output model can be employed to estimate economy-wide impacts of Hawaii's seed industry. Seed industry outlays of more than $240 million statewide in 2012 were associated with almost $500 million in total output, with more than 1,400 jobs directly and indirectly and, including induced effects, with nearly 2,800 jobs and $32 million in state taxes (see Table 1).[9] More than just seed is produced: in Hawaii the winter nurseries also serve as part of the global research and development arms of the major global seed companies. The seed industry is at the forefront of knowledge-based industry in Hawaii.[10]

Table 1
Direct, indirect, and induced economic impacts
of Hawaii's statewide seed industry

	Direct and indirect effects				Including induced impacts			
Million 2012 dollars except jobs	Output	Earnings	Jobs	State taxes	Output	Earnings	Jobs	State taxes
Loudat and Kasturi (2013)								
Operating expenditure impacts	264.4	69.2	1,397	-	501.8	251.0	2,321	26.9
Capital expenditure impacts (2010)	25.1	7.2	96	-	49.1	12.0	206	2.5
Brewbaker (2014)								
Gross operational impacts (2012)†	314.5	163.7	1,444	28.6	481.7	219.7	2,816	31.9
Production impacts*	211.4	102.6	905	19.2	302.0	137.7	1,765	20.0
Non-production impacts (e.g. R&D)†	103.1	61.1	539	9.4	179.7	81.9	1,050	11.9
Addendum (using I-O model):								
Seed sales (99.7% corn)*	174.4	103.2	911	13.8	303.8	138.6	1,776	20.1

**2012 Census of Agriculture* (*Hawaii*) (May 2014); actual production expense was $151.5 million; multiplier effects assume only R&D related activity

†USDA NASS and Hawaii DOA (revised April 2014); total outlay was $241.6 million

Note: this report relies on updated (2007, 2012) input-output multipliers (State of Hawaii DBEDT (December 2013))

Sources: Author's calculations using the State of Hawaii input-output model published in Hawaii DBEDT, Research and Economic Analysis Division (revised December 2013) *The Hawaii State Input-Output Study: 2007 Benchmark Report* (http://dbedt.hawaii.gov/economic/reports_studies/2007-io/), USDA National Agricultural Statistics Service (April 11, 2014), *Hawaii Seed Crops Report* (http://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Sugarcane_and_Specialty_Crops/2014HawaiiSeedCrops.pdf) and Thomas Loudat and Prahlad Kasturi (February 2013), *Hawaii's Seed Crop Industry: Current and Potential Economic and Fiscal Contributions*, Honolulu: Hawaii Crop Improvement Association, Hawaii Farm Bureau Federation (http://www.hciaonline.com/wp-content/uploads/2013/04/2012-Seed-Industry-Economic-Data-Report.pdf). Earlier work also is referenced at Thomas Loudat and Prahlad Kasturi (July 2009), (http://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Miscellaneous/SeedEcon.pdf)

The agricultural census estimate of the market value of the seed industry's production in 2012 was approximately $150 million out of approximately $666 million in all Hawaiian agricultural receipts. Thus, Hawaii seed industry sales comprised 23 percent of the market value of all Hawaii crop products that year (see Table 2). This single agricultural activity generates nearly one-quarter of all farm receipts in Hawaii, before counting seed industry's R&D activity.

Equivalently, the seed industry farms 23 percent of Hawaii agricultural acreage exposed to the application of insecticides including treatments for nematodes. Hawaii's seed industry footprint comprises less than 9 percent of all the farm acreage treated with herbicides in the islands.[11] Smaller acreages are treated for diseases. Collectively, contrary to popular mythology, the seed industry in Hawaii is *not* a comparatively heavy user of agricultural chemicals such as pesticides. As reported in Table 2, overall seed industry acreage exposure to agricultural chemicals is only 10 percent of the Hawaii farm acreage total. This is but a fraction of its 23 percent share of Hawaii farm receipts. Urban—not agricultural—applications are the most likely potential sources of environmental exposure to pesticide residues in the Hawaiian Islands.[12] No epidemiological evidence for adverse human health effects has arisen in the seed industry's fifty-year history in Hawaii pointing to it as a smoking gun.[13]

Table 2

Selected Hawaii seed industry and other agriculture data
from the USDA Census of Agriculture for Hawaii (May 2014)

	Unit	**Total**	**Other**	**Seed***	**Other as % of Total**	**Seed as % of Total**
Farms and income						
Farms	number	7,000	6,988	12	99.8	0.2
Land in farms	acres	1,129,317	1,107,015	22,302	98.0	2.0
Crop and livestock values						
Market value of products sold	million$	*661.347*	*508.948*	*152.399*	*77.0*	*23.0*
Value of government payments	million$	5.228	5.228		100.0	0.0
Addendum: sold directly to individuals	million$	13.215	13.215		100.0	0.0
Fertilizers and chemicals applied						
Fertilizers	acres	109,503	100,467	9,036	91.7	8.3
Manure	acres	5,165	5,165	-	100.0	0.0
Herbicides	acres	114,713	105,295	9,418	91.8	8.2
Insecticides†	acres	34,506	26,466	8,040	76.7	23.3
Treated for disease (crops, orchards)	acres	9,143	6,484	2,659	70.9	29.1
Other chemicals‡	acres	19,000	19,000	-	100.0	0.0
All agricultural chemicals	acres	*292,030*	*262,877*	*29,153*	*90.0*	*10.0*

*Corn comprised 99.7 percent of seed sales; all data are for NAICS industry code 1111, oilseed and grain farming

†Includes treatment for nematodes

‡Used to control growth, thin fruit, ripen, defoliate

Source: Table 68; U.S. Department of Agriculture (USDA) National Agricultural Statistical Service (NASS) (May 2014): *2012 Census of Agriculture* (*Hawaii*) (http://www.nass.usda.gov/Statistics_by_State/Hawaii/ and http://www.agcensus.usda.gov/Publications/2012/Full_Report/Census_by_State/Hawaii/index.asp).

The potential loss of a quarter billion dollars in economic activity in Hawaii and, through economic linkages, one-half billion dollars in economy-wide activity each year from GMO exclusion would be significant and adverse. The potential loss of such economic activity and its integration of Hawaii's economy into a global nexus of research and development activity would be even more catastrophic. Positive external benefits arise from the industry's presence in Hawaii. It creates a critical mass of R&D and agricultural production activity with which the academic community, graduating students, agricultural services suppliers, and offshore agribusiness interests all interact.

Unlike other high-tech industry the state has attempted to attract with subsidies, this biotech seed industry emerged solely through private investment. The seed industry generates economic opportunity and employment for highly-skilled and technical workers, alongside seasonal agricultural employment for workers seeking part-time jobs, all without government support. More than a billion dollars of public funds, given away to investors through state tax credits, has had little success while Hawaii's seed industry thrives independently, without subsidization. (See the Appendix.)

Hawaii's seed industry is an investment in *knowledge capital formation*. It's not about food production for consumption—in seed production the output is an *input*. It's about developing and replicating the software, the maize genome. It's about contributing to worldwide crop improvement in maize. It's about using resources more efficiently. It's about feeding a billion starving people in the world today, and improving their nutrition. It's about global food security. Productivity growth in the maize genome is about potentially reducing human dependence on expanding agricultural land use, about mitigating global deforestation, and about the possibility of restoring natural environments.

Hawaii's participation in the research and development nexus around the maize genome is so pivotal that the islands have become a crucial component of global genetics-based crop improvement. Hawaii is part of the global corn supply chain. There isn't a corn plant in the world that doesn't have a genetic relationship to Hawaii. For many of the same reasons that other economic activities, like tourism, became possible in Hawaii, the seed corn industry has been Hawaii's only major, sustained agricultural growth sector since statehood relying solely on comparative advantages of Hawaii's location and the entrepreneurship of its founders.

Maui County seed industry economic impacts

The corn seed industry in Hawaii started on Molokai nearly a half century ago, and has grown to become as much as one-quarter of all Maui County agricultural activity today. Among the more notable economic impacts of Maui County's seed industry:

- $55.8 million in direct and indirect seed industry annual impacts on Maui County economic output through employment, suppliers, and services providers.

- $84.2 million in total Maui County economic output including the induced effects of household consumption from incomes originating in the seed industry.

- Nearly 770 jobs directly and indirectly associated with the seed industry, and more than 950 jobs including consumption effects.

- At least $4.0 million in state taxes (and additional county property taxes)

- The most significant private industry source of external receipts besides tourism, and nearly ten percent of all private sector jobs, on Molokai.

- Accumulation of human capital and technical knowledge.

These economic impacts are estimated using the Hawaii input-output model using a methodology developed by the author in the spirit of earlier estimates of the statewide seed industry's economic impacts by Loudat and Kasturi (2013) (see endnote 9).[14] Detailed Maui County estimates are summarized in Table 3, below:

Table 3
Direct, indirect, and induced total economic impacts
of Maui County's seed industry

Million 2013 dollars	**Output**	**Earnings**	**Jobs**	**State taxes**
Direct and indirect seed industry impacts	$ 55.8	$ 22.6	769	$ 2.6
Including induced impacts (consumption)	$ 84.2	$ 30.4	952	$ 4.0

Sources: Author's calculations using the State of Hawaii input-output model published in Hawaii DBEDT, Research and Economic Analysis Division (revised December 2013) *The Hawaii State Input-Output Study: 2007 Benchmark Report* (http://dbedt.hawaii.gov/economic/reports_studies/2007-io/)

Annual seed industry outlays and employment in Maui County—aside from hundreds of millions of dollars in cumulative capital expenditure—translate through direct, indirect, and induced effects into approximately $84.2 million in total economic output for Maui County.

Seed industry average annual wages are 45 percent higher than average earnings of all workers in Maui County, and are higher than in county and state government and many private sector industries, including health care, finance, and accommodation.[15]

On Maui Island, the seed industry is second only to sugarcane in agricultural importance, even as Maui pineapple reboots. Sugarcane's value has risen with global commodity prices; its share of Maui agricultural value has increased accordingly. Pineapple operations have scaled back to fresh market production of a 1970s hybrid first developed by the Hawaii Pineapple Research Institute but ignored by canners. Data are not available on Maui pineapple cultivation's present-day extent, but acreage is about one-fifth that of 2003, when Maui County fresh equivalent pineapple receipts were less than today's Maui County seed industry outlays.

On the island of Molokai, where the corn seed industry in Hawaii started a half century ago, it is the most significant private industry source of external receipts besides tourism. Seed industry jobs comprise nearly ten percent of all private jobs on Molokai, approximately as many as in accommodation services, in food services, and in county government.[16]

Maui County's seed industry's beneficial economic impacts propagate outward to economy-wide benefits via inter-industry linkages: employees, suppliers, and services providers all earn incomes from this farming activity. They, in turn, are consumers of goods and services provided by others in Maui County. All these effects are captured in the total economic impact calculation, in the $84.2 million in direct, indirect, and induced economic impacts. The seed industry is too important to shut down without adverse, economy-wide impacts in Maui County.

Maui and Molokai seed companies are concentrations of high-skill, high-productivity agricultural production based on research and development activity. Maui County seed companies produce and distribute what research and development has created. This generates economic benefits not just through the conventional inter-industry linkages but also by creating fruitful nodes for collaboration among skilled technical workers. Interaction within these firms generates external benefits for the community through agricultural and scientific leadership, innovation, mentoring, and education. These benefits are not customarily captured in conventional metrics for economic activity.

As with all farming, fifty years of the seed industry in Maui County has woven it into the economic fabric of the community. The many contributions of industry participants to the community are like those of others in the community, with special emphasis on agriculture and science education and leadership. Some of them include:

- More than 3,500 volunteer hours per year by seed industry employees in service to the community.
- Nearly $200,000 per year in charitable contributions to the community by industry workers, including fundraising activities for local schools
- More than $20,000 per year in scholarships for students in agriculture and life sciences, and paid internships for both high school and college students
- More than $35,000 per year in donations for science, technology, engineering, and mathematics (STEM) education in local schools

Maui and Molokai sugar cane and pineapple plantations, beginning more than a century ago, provided centers of employment around which communities developed that are still interwoven in Maui County's social and cultural fabric. The legacy of their myriad influences on modern life and contemporary culture is enduring. Plantation communities were concentrations of economic activity in which the unintended, uncompensated benefits of co-location were enjoyed by members of the community irrespective of social status or economic roles. Today, Maui County's seed industry has created new nodes of economic activity pooling skilled, technical and scientific employment with traditional farm labor into new communities of collaboration and production.

Maui County is no longer an economy that produces widgets. It does not primarily produce *things* in today's globalized economy. Maui County is an economy that produces services and information. Economic size no longer is measured in terms of output defined by counting up how many things are produced. Today, the size of the economy is measured in terms of the value of economic *activity* in industries. Maui County's seed industry is a metaphor for the evolution of the islands' economy from a commodity-producing/exporting economy to an information- and services-producing/exporting economy. The seed industry combines the professional, technical, and scientific services in genetics-based crop improvement with seed production as a large-scale farming activity. Seed production is the vehicle for dissemination of the "software" incorporating genetic improvements, the information itself. Maui County's seed industry *is* the New Economy.

Genetics and agronomy

Genetic modification in Maui County agronomic research, and seed production of genetically-modified varieties, both occur under strong management and ethical protocols, reinforced by regulatory oversight of the U.S. Department of Agriculture, the Environmental Protection Agency, and the Food and Drug Administration, along with collaborating state agencies. These agencies also regulate pesticide use. Peer-reviewed scientific research assesses all aspects of genetic modification including new techniques like cisgenesis and intragenesis.[17] All of the major forums for scientific consensus support genetic modification research and development and support farming of genetically-modified crops. None recommend banning such genetic engineering or the associated products. The American Association for the Advancement of Science,[18] the American Medical Association,[19] the European Union,[20] the National Academy of Science,[21] and the Crop Science Society of America[22] establish broad scientific support for genetic modification and underscore the safety of resulting products.

The seed industry is about the *software*, the maize genome. In Hawaii, the industry enjoys U.S. intellectual property protections unavailable elsewhere in the tropics around the world. The seed industry pivotally engages Hawaii in a global collaboration that has tripled U.S. agricultural multi-factor productivity during the last 65 years.[23] Virtually every commercially-grown corn plant in the world is part of Hawaii's maize ohana. Genetic modification has raised crop yields, increased disease resistance and drought tolerance, boosted nutritional value, and has directly *reduced* global insecticide and herbicide use. In this century genetic modification in maize holds the potential not only to reduce world hunger but also to contribute to reducing the amount of agricultural land necessary to feed humanity.

Opponents of agricultural biotechnology narrowly focus on transgenic modification, but genetic modification more widely has been a conventional method of crop improvement for almost a hundred years, and characteristic of human civilization since the domestication of animals and the dawn of agriculture 12,000 years ago. Only since the early twentieth century has the science of genetics been well-understood, but genetic modification has been unknowingly practiced throughout modern human history, beginning with selection methods to domesticate animals and to grow plants expressing genetic characteristics favorable for human use.

Transgenic methods which acquire genetic materials to be introduced into corn and other crops have been around for more than thirty years. No material adverse impacts of these practices on humans or the environment have been documented in the scientific literature. A prudent posture of vigilance in the monitoring of potential impacts is the industry standard. Neither vigilance nor study requires pre-emptive shutdown of the industries engaged in genetic modification or the cultivation of such organisms.

Newer, cisgenic methods apply the same techniques between closely-related organisms that could otherwise be conventionally bred. Unlike conventional breeding methods which transmit entire packages of genetic content to offspring, including useful as well as less useful attributes, cisgenic modification (like transgenic modification) transmits only a particular, desirable genetic characteristic. One of the reasons it is important not to impair the activity of Maui County's corn seed industry is to enable such refinements in scientific technique to proceed to be integrated into industry practice.

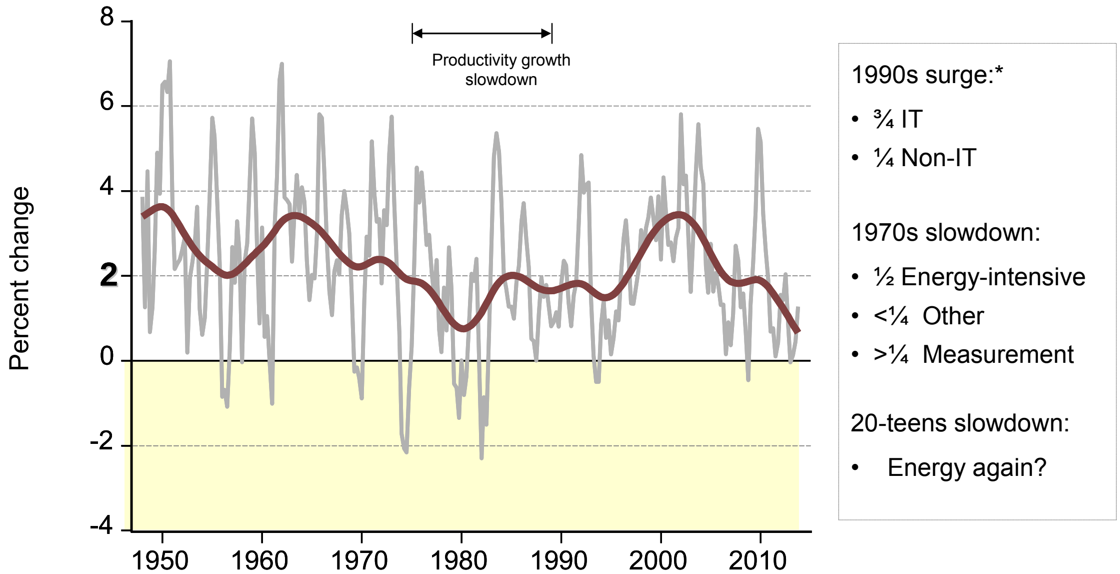
Rather than recognize the global role of Hawaii's seed industry, advocates of the Maui initiative to ban cultivation of genetically-modified crops substitute emotion for science-based discourse. The Maui initiative bill's asserts that "cultural and spiritual heritage will suffer irreparable harm if...Maui County is contaminated by GE Operations and Practices."[24] Yet, a half century of continuous seed industry operations in Maui County, and two decades of transgenic cropping, has failed to provide *any* evidence of harm or contamination. No evidence causally has associated either genetic modification or other seed industry activities with any adverse outcome.

The Maui anti-GMO initiative seeks to shut down the seed industry and ban genetically-modified agricultural crops because of *faith* in the assertion that Maui "will suffer irreparable harm." Faith is the belief in something that *cannot* be disproven. Scientific hypotheses *can* be disproven, which is why the acceptance of genetic modification by all major scientific consensus-building organizations is so important. Thousands of scientific studies and decades of scientific research have failed to disprove the hypothesis that genetically-modified crops and agriculture are safe for humans and the environment. Nothing prevents Maui County also from studying the impacts of genetic modification techniques, but Maui County cannot pre-empt industry without evidence of harm or wrong-doing.

Dynamic gains from Maui County's seed industry

Maui County's seed industry epitomizes the type of applied agronomic activity necessary to sustain high rates of productivity increase that are responsible for rising living standards worldwide. In the U.S., twentieth century productivity growth has waxed and waned (see Figure 4).[25] Long-term output per hour of U.S. private business quadrupled during the last 65 years, averaging 2 percent annually.[26] Slightly less than half of that increase came from growth of productive factors such as capital per worker. Slightly more than half of that increase came from multifactor productivity growth, primarily through technological progress, improved operations management, and institutional changes among other factors.

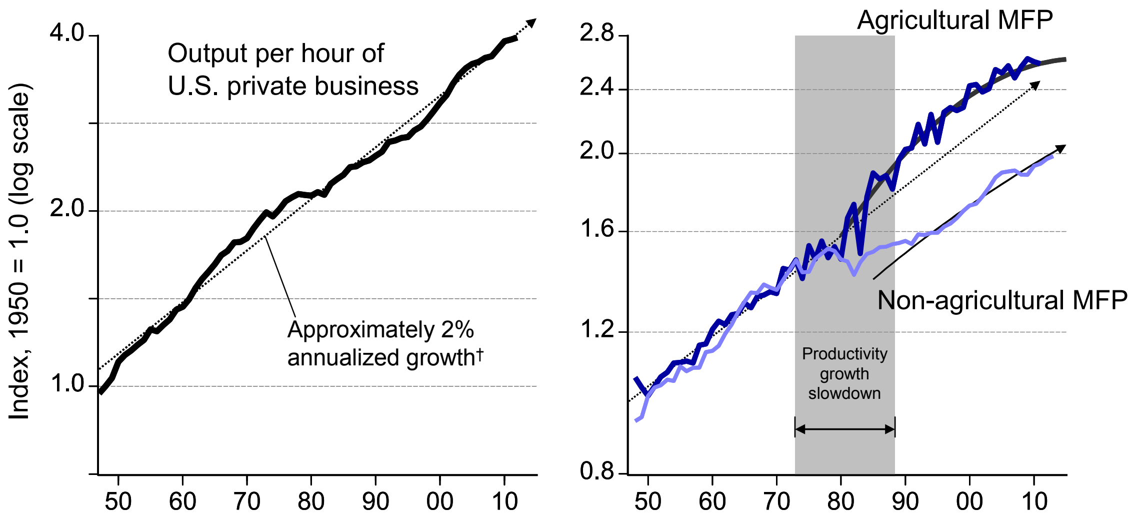
Figure 4
Annual growth in percent of U.S. private business output per hour: "productivity growth"



Sources: Federal Reserve Bank of St. Louis (http://research.stlouisfed.org/fred2/series/OPHNFB), BLS (http://www.bls.gov/mfp/tables.htm), Kevin J. Stiroh (December 2002) "Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?" *American Economic Review* **92**:5 pp. 1559-76 (http://www.newyorkfed.org/research/staff_reports/sr115.html); William Nordhaus (November 24, 2004), "A Retrospective on the Postwar Productivity Slowdown" *Cowles Foundation Discussion paper No. 1494*, Yale University (http://papers.ssrn.com/sol3/papers.cfm?abstract_id=625182)

Agricultural multifactor productivity (MFP) growth is the portion of productivity increase that cannot be attributed to more equipment, land, fertilizer, or infrastructure such as irrigation. It represents technological progress. Agricultural MFP nearly tripled during the last 65 years, and it has outstripped non-agricultural MFP since the 1970s (see Figure 5).[27] Agricultural productivity has grown at a rate of about 1.4 percent per annum for two-thirds of a century, surging in the decades following the introduction of transgenic modification techniques.[28] A large portion of agricultural MFP growth is attributable to genetics-based crop improvement.[29]

Figure 5
Indexes of U.S. private business output per hour
and multi-factor productivity (MFP); "Technological progress"



†Regression on log trend yields growth rate of 2.06% (1947-2013)

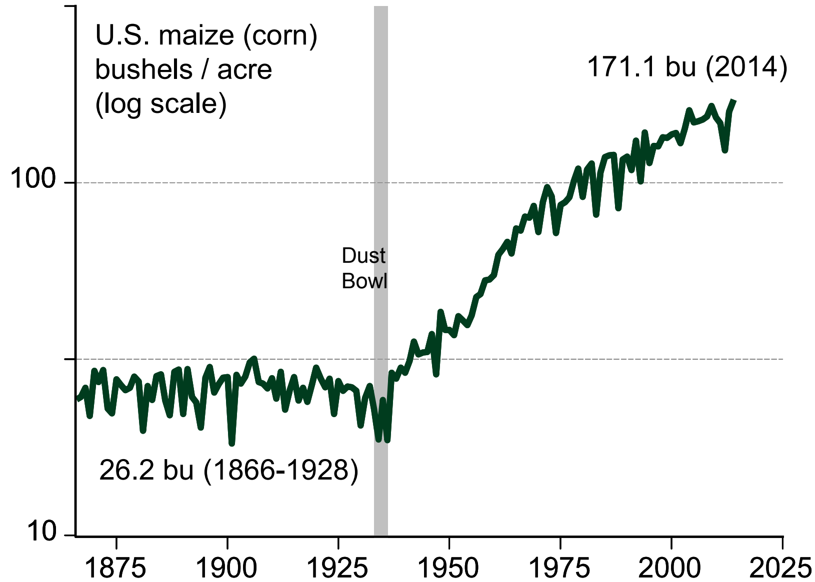
Multifactor productivity measures growth in output separable from the portion attributable to inputs—technological progress, efficiency improvements, returns to scale, resource reallocations, other influences.

*Multifactor productivity growth trends:
1. Agricultural ≤ 1.4% (1948-2012)
2. Non-agricultural ≤ 1.2% (since 1995)

Source: Federal Reserve Bank of St. Louis (http://research.stlouisfed.org/fred2/series/OPHNFB), BLS (http://www.bls.gov/mfp/tables.htm), and USDA (http://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us.aspx#28268); nonfarm revisions July 2014 (http://www.bls.gov/mfp/mprdload.htm); index re-basing and trend regressions by TZ Economics

The seed industry links Maui County to global research and development in the maize genome. Genetics-based advances have raised crop yields, increased resistance to disease and pathogens, introduced hardiness and survivability under more extreme weather conditions, conserved water resources through drought tolerance, boosted nutritional attributes from proteins and sugars to specific molecules such as carotenoids, enabled significant reductions in pesticide use, facilitated farm operations to emit smaller atmospheric carbon and other greenhouse gas emissions levels, and supported farm operations that embrace soil conservation techniques. Maui County has been a part of this progress for more than a half century. The seed industry is how Hawaii *makes* multifactor productivity growth.

Figure 6
U.S. annual corn yields, 1866-2014



Source: USDA National Agricultural Statistics Service (http://quickstats.nass.usda.gov/); "USDA Forecasts Record-High Corn and Soybeen Production in 2014 Cotton Production also Up from 2013" (August 12, 2014) (http://www.nass.usda.gov/Newsroom/2014/08_12_2014.asp)

One area of multi-country empirical research associates a subset of transgenic maize improvements focused on insect-resistance with rising yields in many different countries. Yield increases ranged from 5 to 24 percent (a cumulative 5.7 percent for all countries in the sample) over a ten year period, 1996-2006. Quantitatively similar results have been associated with herbicide tolerance. Research suggests that corn prices over the same decade would have been almost 6 percent higher without the introduction of biotech corn varieties.[30] Loosely speaking, more is better and more is cheaper. Of course, transgenic techniques aren't the only genetic methods of Hawaii's seed industry, but these biotech results are notable.

Hawaii's pivotal global role in corn seed production, genomic research and development, its connection with the entire planet's commercial agricultural maize gene pool, makes what happens in Maui County pertinent. Corn remains one of a handful of major staple grains consumed worldwide.[31] Maui County occupies the same part of the tropics from which modern maize (corn) emerged from the grass *teosinte*. Its evolutionary origins are from similar latitudes in Central America. Sustaining productivity growth in corn and in other grain genomes is necessary for extending higher living standards to the large portion of the world where people still go to bed hungry at night. Productivity growth, first through 19th century mechanization and industrialization, more recently through 20th century technological progress including biotechnological progress, is responsible for the dramatic improvement of human living standards of the last two centuries, overcoming the Malthusian trap.[32]

The Malthusian trap is that if land is in fixed supply as a productive factor and is technology is changing only slowly, population growth raises the ratio of labor to land, reducing agricultural productivity.[33] The Industrial Revolution initially provided an escape from this trap in the early 1800s: more and better equipment overcame the fixed quantity of arable land. Fewer workers were required in agriculture, freeing up workers for manufacturing and other occupations. Twentieth-century technological progress further improved productivity of physical capital, and genetics and biotechnology were among the most important methods raising agricultural land productivity. Today, land has become a negligible part of the capital stock in modern economies, while population growth "has only second-order effects for output per head."[34]

Population growth in Maui County and in the developed world subsided during the twentieth century, declining to around 1 percent, while productivity growth rose to 2 percent. This *inverted* the Malthusian trap. The demographic transition arose from reductions both in mortality and in fertility.[35] Productivity growth then sustained rising living standards. Productivity growth has not only improved health and extended lives, it has enabled profound social change. Women are free to participate more actively in the labor market. Young people are able to invest in human capital formation for a greater portion of their lives. Leisure time has increased universally. Technological progress has flowed directly from research and development activities, and Maui County's corn seed industry has been a participant in the production and distribution of an important class of R&D outputs.

These profound changes have not prevented people from embracing the lump of labor fallacy, the supposition that with a limited number of jobs, technological progress displaces workers. Autor (2014) describes this fallacy as "intuitively appealing and demonstrably false." He observes that 41 percent of the U.S. workforce in 1900 was employed in agriculture, but only 2 percent were employed in agriculture in 2000. Autor writes:

> *This Green Revolution transformed physical and cognitive skills demands and the fabric of American life. But it did not reduce total employment. The employment-to-population ratio rose over the twentieth century as women moved from home to market. ...Over the long run, technological improvements create new products and services, raise national income, and increase demand for labor throughout the economy.*[36]

U.S. agriculture is so productive that today, comprising only 1 percent of GDP, it is more than 9 percent of U.S. merchandise exports. The U.S. grows a surplus that feeds the world.

Agricultural productivity growth has also transformed Hawaii's economy. In 1900, agricultural workers comprised 62 percent of Hawaii's workforce; only 1.25 percent of workers were employed in Hawaii agriculture in 2011.[37] More than three-fifths of Hawaii's workers had to work in agriculture a century ago simply to feed the population at a near-subsistence level. Today, scarcely one percent of Hawaii workers, engaged in global trade, assure the islands access to more food than people can eat. Hawaii's living standards are much higher than one hundred years ago. Workers enjoy much greater leisure time. With today's incomes an array of new technologies provide access to unprecedented sources of information and entertainment content at levels of quality unimaginable a century ago. In 2011, 2.4 percent of Maui County workers—nearly twice the statewide proportion—were employed in agriculture. This is a testimony to the continuing relative importance of Maui's sugar cane, corn seed, and other agricultural industries. At the same time, it is a validation of the tremendous economic benefits to all Hawaii workers of agricultural productivity and technological advances in transportation, logistics, and distribution that enable the pursuit non-agricultural economic activities.

Two centuries of industrialization and productivity growth grounded in technological progress have changed the structure of employment, but not by extinguishing jobs. Jobs are extinguished *and* invented through a process of creative destruction.[38] Dynamic labor market outcomes are complex. American labor markets recently have become concentrated in high-skill, high-wage jobs *and* in low-skill, low-wage jobs. This polarization has left out mid-skilled, mid-wage workers, facing international competition.[39] Partly in response, Hawaii economic policy-makers have sought to achieve economic diversification focused on higher-paying, higher-skilled jobs. Skills formation receives special public policy emphasis. Recognition of the importance of early-childhood acquisition of cognitive and non-cognitive skills has led Hawaii to expand public pre-school educational opportunity.[40] Skills matter, and Maui County's seed industry is a leading example of skills-based biotechnology employment.

Hawaii's economy itself has evolved from a more goods-producing economy to a more services- and information-producing economy. A half century ago, in 1963, agriculture comprised 5.6 percent of Hawaii gross domestic product, construction and manufacturing were 14.7 percent of GDP, and non-financial private services comprised 10.9 percent of GDP. By 2013, agriculture was 1.0 percent of Hawaii GDP, construction and manufacturing were 7.4 percent, and non-financial private services were 18.5 percent of GDP.[41] The rise of tourism dominated economic growth during the first 25 years of statehood, but tourism's share of Hawaii GDP actually declined from 25 percent of the total to about 15 percent over the last two decades.[42] Real—inflation-adjusted—Hawaii tourism receipts declined *absolutely* during the last 25 years, not just relatively.[43] Something else must grow. Hawaii's seed industry has.

Dynamic economic gains from Maui County's seed industry are part of the benefits associated with productivity growth that the industry makes possible. In the future, agricultural productivity growth may enable marginal agricultural lands to be freed up and restored to natural environments, contributing to a reversal of global deforestation and to an increase in global atmospheric carbon sequestration. Genetic modification enables economic growth on the *intensive* margin to substitute for growth on the *extensive* margin. In the new services and information economy that Maui County has become, the seed industry exemplifies high-skill, high-wage employment in pursuit of productivity growth as a contribution to the global advance of human welfare. Fear should not replace science at the forefront of Maui County's ongoing, structural economic evolution. Its corn seed industry need not be shut down.

Appendix 1

Table 4: Detailed Agricultural Census statistics

Hawaii seed industry and other agriculture data
from the USDA Census of Agriculture for Hawaii (May 2014)

	Unit	Total	Other	Seed*	Other as % of Total	Seed as % of Total
Farms and income						
Farms	number	7,000	6,988	12	99.8	0.2
Land in farms	acres	1,129,317	1,107,015	22,302	98.0	2.0
Market value of products sold	million$	661.347	508.948	152.399	77.0	23.0
Value of government payments	million$	5.228	5.228		100.0	0.0
Addendum: sold directly to individuals	million$	13.215	13.215		100.0	0.0
Farm production expenses						
Fertilizer	million$	46.584	30.538	16.046	65.6	34.4
Chemicals	million$	32.993	18.755	14.238	56.8	43.2
Seeds, plants, vines, trees	million$	18.825	8.753	10.072	46.5	53.5
Fuels and utilities	million$	61.331	53.002	8.329	86.4	13.6
Labor	million$	291.525	210.711	80.814	72.3	27.7
Other expenses not included elsewhere	million$	127.801	111.442	16.359	87.2	12.8
Total excluding expenses not available for seed industry and depreciation	million$	579.059	433.201	145.858	74.8	25.2
Addendum:						
Other expenses not available for seed†	million$		28.507	(D)		
Depreciation	million$	50.584	44.953	5.631	88.9	11.1
Fertilizers and chemicals applied						
Fertilizer, lime, soil conditioners	acres	109,503	100,467	9,036	91.7	8.3
Manure	acres	5,165	5,165	-	100.0	0.0
Treated for insects	acres	30,417	22,377	8,040	73.6	26.4
Treated for weeds, grass, brush	acres	114,713	105,295	9,418	91.8	8.2
Treated for nematodes	acres	4,089	4,089	-	100.0	0.0
Treated for diseases in crops and orchards	acres	9,143	6,484	2,659	70.9	29.1
Chemicals used to control growth, thin fruit, ripen, defoliate	acres	19,000	19,000	-	100.0	0.0
Note: treated for insects *and* nematodes	acres	34,506	26,466	8,040	76.7	23.3

*Corn comprised 99.7 percent of seed sales; all data are for NAICS industry code 1111, oilseed and grain farming
†Equipment leases, interest expense, property taxes
(D) Data withheld to avoid disclosure of individual operations

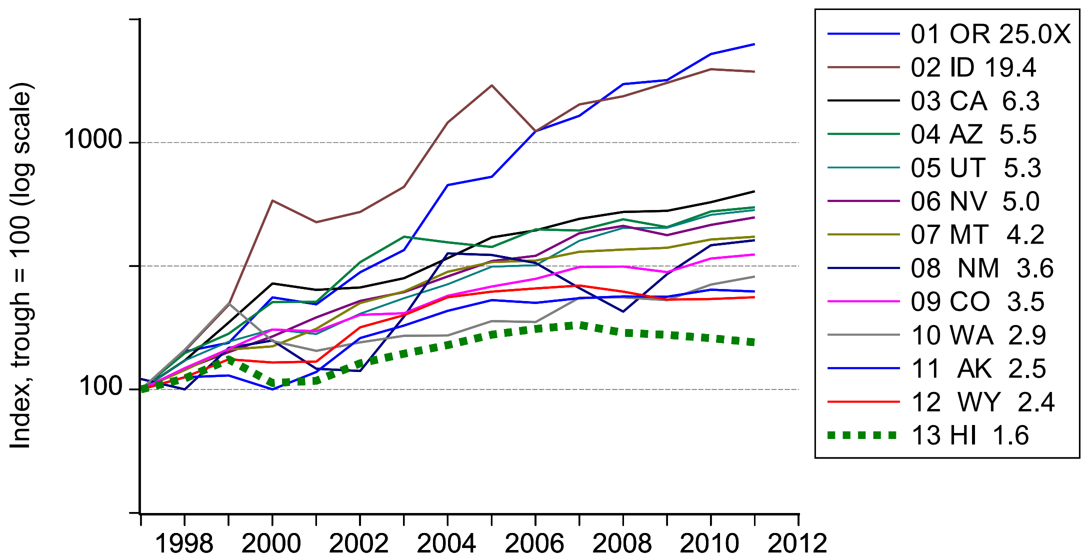
Source: Table 68; *2012 Census of Agriculture* (Hawaii) (May 2014)

Appendix 2: Hawaii's high-tech subsidy FAIL

Hawaii's failed experiment with high technology tax credits (Act 215/221) involved transferable, nonrefundable 100 percent investment tax credits. Essentially no upper bounds were imposed: capital infusions could be partitioned into multiple investments. The law contained no measurement requirements to gauge if outcomes aligned with policy intent. No official impact estimate for the State's $1 billion in tax expenditures over ten years is available. An interim assessment by the Hawaii Tax Review Commission 2005-2007 suggested that "the test of the effectiveness of the statute should include whether new—as in not otherwise operated—high technology enterprises are formed, and, as viable entities, increase the State of Hawaii's economic base." [1] The Hawaii State Auditor in 2012 reported that the law still "did not contain any goals and performance measures."[2] Data illustrated in Figure 7 suggest that, in any event, the relevant economic base did not grow in Hawaii as elsewhere in the western U.S.

Figure 7

Growth of value-added in Information, Communications, and Technology (ICT) (NAICS code 106), ranked by total net increase, 1997-2011 (in multiples of the 1997 base)



Source: Bureau of Economic Analysis, U.S. Department of Commerce (http://bea.gov/regional/index.htm), trough dates are all 1997 except for New Mexico (1998); peak dates are all 2011 except for Hawaii and Wyoming (2007), and except for Alaska and Idaho (2010); indexing by TZE.

[1] Marcia Sakai and Bruce Bird (December 2006), *Report of the 2005-2007 Tax Review Commission Appendix B: Measuring the Costs and Benefits of Hawaii's Qualified High Technology Business (QHTB) Investment Tax Credit under Act 221 and Act 215* (http://files.hawaii.gov/tax/stats/trc/docs2007/Final_Report-Appendix_B.pdf).

[2] Hawaii State Auditor (July 2012), *Audit of the Department of Taxation's Administrative Oversight of High-Technology Business Investment and Research Activities Tax Credits*, Report No. 12-05 (http://files.hawaii.gov/auditor/Reports/2012/12-05.pdf).

Endnotes

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[1] A BILL PLACING A MORATORIUM ON THE CULTIVATION OF GENETICALLY ENGINEERED ORGANISMS certified by Danny A. Mateo, Maui County Clerk, June 13, 2014, (COUNTY COMMUNICATION NO. 14-166), in its section 7 of the proposed temporary moratorium envisions a two-phased study process funded by an independent "person or entity," rather than Maui County, engaging "scientists and health experts" and a "professional consultant" to determine the study's *scope* within 90 days, followed by another 30 days of public input, 18 months of subsequent study and publication of the report, followed by 90 more days of public comment before Maui County can reconsider—amend or repeal—the moratorium.

[2] See Lance Gibson and Garren Benson (revised 2002), *Origin, History, and Uses of Corn* (Zea mays), Iowa State University Department of Agronomy (http://agron-www.agron.iastate.edu/Courses/agron212/readings/corn_history.htm); Paul C. Mangelsdorf (1974) *Corn: Its Origin, Evolution and Improvement*, Belknap Press, Harvard University; and Sean B. Carrol (May 24, 2010), "Tracking the Ancestry of Corn Back 9,000 Years," *The New York Times* (http://www.nytimes.com/2010/05/25/science/25creature.html?_r=0).

[3] David Livingston Crawford (1937). *Hawaii's Crop Parade*. Honolulu: Advertiser Publishing Co., Ltd.

[4] James L. Brewbaker (1996). *Corn Production in Hawaii*. University of Hawaii College of Tropical Agriculture and Human Resources.

[5] Crawford (1937), cited in fn. 3 notes that, beginning in 1917, resistance to the leaf-hopper and mosaic virus were investigated at the Hawaii Experiment Station (then federal) and the College of Hawaii (now UH). Professor Henke reported in 1928 on his lack of success; Professor Krauss complained of falling corn yields. Both professors now have namesake buildings at the University of Hawaii. Only Caribbean corn varieties from Cuba and Puerto Rico showed mosaic virus resistance in these early 20th century Hawaii trials. This is consistent with the hypothesis that, as the maize mosaic virus migrated across the Caribbean from modern-day Venezuela to the Yucatan, it posed a catastrophic threat to classic Maya and Mesoamerican cultures. It is also consistent with corn's early-20th century success in Hawaii uplands, but not lowlands. See James L. Brewbaker (1979), "Diseases of maize in the wet lowland tropics and the collapse of the Classic Maya civilization," *Economic Botany* **33**, pp. 101-118.

[6] This early history is documented in J.L. Brewbaker and D. E. Hamill (1967), "Winter corn seed production on the Island of Molokai," *Hawaii Agricultural Extension Service Technical Progress Report* **160**:11, and J.L. Brewbaker (ed.) (1969), "Corn seed production in Hawaii; Present problems and future potential" *Proceedings of the 1st Hawaii Seed Industry Conference, Molokai, Hawaii*.

[7] Figure 1 illustrates a half century of Hawaii agricultural production, measured in millions of dollars in annual activity, either in terms of farm gate receipts or, in the case of the seed industry, outlays. Figure 2 illustrates seed industry detailed data on crop acreage and outlays.

[8] Survey farm-level data from three midwestern states (Iowa, Minnesota, and Wisconsin) over four years estimates organic corn yields about 70 percent that of conventional crops. See Ariel Singerman, Chad E. Hart, Sergio H. Lence (August 2011), "Price Analysis, Risk Assessment, and Insurance for Organic Crops," *Iowa State University Center for Agricultural and Rural Development Policy Brief 11-PB 6* (http://www.card.iastate.edu/policy_briefs/display.aspx?id=1163), and USDA (http://quickstats.nass.usda.gov/).

[9] Hawaii DBEDT, Research and Economic Analysis Division (revised December 2013) *The Hawaii State Input-Output Study: 2007 Benchmark Report* (http://dbedt.hawaii.gov/economic/reports_studies/2007-io/), and Thomas Loudat and Prahlad Kasturi (February 2013), *Hawaii's Seed Crop Industry: Current and Potential Economic and Fiscal Contributions*, Honolulu: Hawaii Crop Improvement Association, Hawaii Farm Bureau Federation (http://www.hciaonline.com/wp-content/uploads/2013/04/2012-Seed-Industry-Economic-Data-Report.pdf). Earlier, related work also may be found by Thomas Loudat and Prahlad Kasturi (July 2009).

(http://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Miscellaneous/SeedEcon.pdf). A comparison of findings is included in Table 1.

[10] Hawaii spent more than a billion dollars in the last decade subsidizing "qualifying high technology businesses" (QHTB). Hawaii's seed industry has thrived—becoming Hawaii's largest agricultural activity—without government subsidies. In spite of QHTB subsidies, Hawaii ranks dead *last* among western states in terms of growth of growth of value-added in Information, Communications, and Technology (ICT; NAICS code 106), ranked by total net increase, 1997-2011, in multiples of the 1997 base. Gross product by industry data for states are from the U.S. Department of Commerce, Bureau of Economic Analysis (http://bea.gov/regional/index.html). The leading western state's ICT sector, Idaho's, grew 25 times its original size. Hawaii's ICT sector grew 1.6 times. See the Appendix.

[11] Source for data is Table 68 in the U.S. Department of Agriculture *Census of Agriculture (Hawaii)* (May 2014), and the data are for 2012. The $152 million in crop marketings enumerated by the *Census* comprise only 60 percent of Hawaii seed industry outlays, because the remainder of industry activities are in research and development activities that do not necessarily or contemporaneously yield a marketable crop product. The most recent, preliminary estimates for the crop year 2012-2013 were reported at $216.830 million in the USDA National Agricultural Statistics Service (April 11, 2014), *Hawaii Seed Crops Report*, in which the main winter season is identified as November to June (http://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Sugarcane_and_Specialty_Crops/2014HawaiiSeedCrops.pdf). The 10 percent decline in operating outlays in the most recent winter season from two previous years revised at around $240 million was attributed to "operating and organizational changes" in the April 2014 NASS report. See also See U.S. Department of Agriculture, National Agricultural Statistics Service (May 2014), *Census of Agriculture 2012: Hawaii State and County Data Vol. 1 Geographic Area Series Part 11* (AC-12-A-11), Tables 36 and 37 (http://www.agcensus.usda.gov/Publications/2012/Full_Report/Census_by_State/Hawaii/index.asp).

[12] In December 2013 and January 2014, responding to "growing community concerns about possible offsite impacts of currently used pesticides on local communities and ecosystems," the Hawaii Department of Health, Hawaii Department of Agriculture, with the help of the U.S. Geological Survey, conducted studies of surface water and sediment at two dozen sites statewide selected with the cooperation of local stakeholders over a range of varying land uses with the potential to become non-point sources of pollution to surface waters the near-shore marine environments. (See http://eha-web.doh.hawaii.gov/eha-cma/Leaders/HEER/statewide-pesticide-survey, and publicly-available data at http://eha-web.doh.hawaii.gov/eha-cma/Leaders/HEER/pesticides.) Only one or 136 different pesticides or breakdown products was identified in the draft report (May 2014) as exceeding state and federal water regulatory limits, a termiticide used in the past (and banned since 1980). "All other pesticides detected were lower than the most stringent aquatic or human health guideline value." Atrazine was most commonly found, in four out of five sites (of 24), none exceeding regulatory benchmarks. In only two of those sites, one on Maui, were concentrations suggestive of current use. Glyphosate (a.k.a. Roundup) was found in seven sites, but its wide use in residential, commercial, agricultural, and roadside applications does not suggest any particular seed industry link. Study is ongoing.

[13] "In response to numerous community inquiries received by the Hawai'i State Department of Health and the University of Hawai'i Cancer Center, Hawai'i Tumor Registry (HTR) regarding suspected elevated rates of cancer among residents of Kaua'i," the state published a *Report prepared by the Hawai'i Tumor Registry for the Hawai'i State Department of Health: Kaua'i Cancer Cases* (September 2013) (http://eha-web.doh.hawaii.gov/eha-cma/documents/20fb7e6f-de7f-4111-9ff6-ef8d6e547507). According to the Hawaii Department of Health, "The report concludes that that there is no evidence of higher incidence of cancer on the island of Kaua'i overall or for specific geographic regions of the island, as compared to the state of Hawai'i." In contrast, throwing more than 600 workers and their families out of employment would, with certainty, create a greater health hazard than the continued practices and operations (to use the phrase adopted by the initiative bill) of the seed industry in Maui County.

[14] The economic impacts are Maui County-wide estimates based on proprietary information provided by Maui County seed industry participants under a confidentiality agreement to prevent disclosure of individual farm operation details.

[15] Hawaii Department Labor and Industrial Relations, full-year data for 2012 (https://www.hiwi.org/gsipub/index.asp?docid=420).

[16] Hawaii Department Labor and Industrial Relations, full year data for 2013 (https://www.hiwi.org/gsipub/index.asp?docid=421).

[17] See Inger Bæsted Holme, Toni Wendt, and Preben Bach Holm (May 2013), "Intragenesis and cisgenesis as alternatives to transgenic crop development," *Plant Biotechnology Journal* vol. **11**, issue 4, pages 395-407.

[18] The American Association for the Advancement of Science places technological progress at center stage in supporting genetic modification: "Civilization rests on people's ability to modify plants to make them more suitable as food, feed and fiber plants and all of these modifications are genetic. Twentieth century advances in the science of genetics opened the way to using chemicals and radiation as means of accelerating genetic change to produce nutritionally enhanced foods like lycopene-rich Rio Star grapefruit and quite literally thousands of other improved fruit, vegetable and grain crop varieties. Modern molecular genetics and the invention of large-scale DNA sequencing methods have fueled rapid advances in our knowledge of how genes work and what they do, permitting the development of new methods that allow the very precise addition of useful traits to crops, such as the ability to resist an insect pest or a viral disease, much as immunizations protect peoplefrom disease." See the AAAS *Statement by the AAAS Board of Directors On Labeling of Genetically Modified Foods*, (20 October 2012) at http://www.aaas.org/sites/default/files/AAAS_GM_statement.pdf .

[19] American Medical Association (2012), *Report 2 of the Council on Science and Public Health: Labeling of Bioengineered Foods* "Bioengineered foods have been consumed for close to 20 years, and during that time, no overt consequences on human health have been reported and/or substantiated in the peer-reviewed literature."

[20] The European Commission, in *A decade of EU-funded GMO research, 2001-2010* (2010), on 50 projects involving more than 400 research groups and EU research grants of more than EUR 200 million—in addition to EUR 100 million between 1982 and 2001—seeks "to address not only the scientific unknowns but, more importantly, public concerns about the potential environmental impact of GMOs, about food safety, the co-existence of GM and non-GM crops, and risk assessment strategies." The EU report notes that, "To counterbalance the predicted increase in the world population to up to nine billion people by 2050, and the related implication of climate change, science has to develop technologies that increase yields and productivity in a sustainable way, while lowering the demand for fertilisers and pesticides, and adapting crops to match the effects of changes in the environment." Its forward concludes that, "Sound policy, while needing to take account of a wide range of views, must be based on sound science. Accordingly, we will continue to support science on Biotechnologies, including GMOs, in order to ensure that evidence is available for a constructive debate in our societies. See ftp://ftp.cordis.europa.eu/pub/fp7/kbbe/docs/a-decade-of-eu-funded-gmo-research_en.pdf.

[21] Typical of scientific consensus-building organizations, the National Academy of Sciences outlines an ambitious research agenda to build knowledge about genetic engineering's impacts, particular those that are unintended. See United States Institute of Medicine and National Research Council (2004), *Safety of Genetically Engineered Foods: Approaches to Assessing Unintended Health Effects*, National Academies Press. pp R9-10, which states, in part, "In contrast to adverse health effects that have been associated with some traditional food production methods, similar serious health effects have not been identified as a result of genetic engineering techniques used in food production. This may be because developers of bioengineered organisms perform extensive compositional analyses to determine that each phenotype is desirable and to ensure that unintended changes have not occurred in key components of food." (http://www.nap.edu/catalog.php?record_id=10977#toc)

[22] The Crop Science Society of America (March 7, 2014), (https://www.crops.org/news-media/releases/2014/0307/618/, full statement at https://www.crops.org/files/science-policy/issues/reports/cssa-gmo-statement.pdf), states:

> *Plant breeding has been used throughout human history to increase desirable traits in plants and animals. With the advent of modern DNA technology, including GM technology, plant breeding has advanced to produce crop*

varieties with pest, disease and drought resistance that have increased yield and input efficiency for farms of all sizes. Productivity in GM crops has delivered gains that are, in some cases, 5-24% higher than conventional varieties. GM technology has also been used to enhance the nutritional content of certain crops. Pro-Vitamin A enhanced rice, high carotene mustard seed oil, Pro-Vitamin A enhanced cassava, even edible vaccines – are just a few of the enhanced crop varieties in development.

In addition to increasing crop yield and nutritional content, GM crops have had considerable positive impacts on the environment. The adoption of GM crops with weed or pest resistance [*has*] *resulted in reduced pesticide spraying and reduced release of greenhouse gas emissions from agriculture. Herbicide tolerant crops have facilitated the continued expansion of conservation tillage, especially no-till cultivation systems, saving nearly one billion tons of soil from erosion each year. In the face of increasingly limited resources, GM technology represents an important tool to improve resource management, increase crop productivity and ultimately help feed a rapidly growing population.*

The statement concludes: "Dozens of acclaimed scientific and health organizations, including the American Association for the Advancement of Science, the World Health Organization, the American Medical Association, and the European Commission, have all conducted similar reviews of the current research and have come to the same conclusion: foods from GM crops are safe for consumption and do not present any health risks."

[23] Agricultural multi-factor productivity grew at a 1.43 percent annualized rate between 1948 and 2011, outstripping non-agricultural productivity. See USDA (http://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us.aspx#28268). The compound annual growth rate of productivity, calculated as the annualized change in output per hour of U.S. private business between 1947 and 2012, was 2.18 percent, and multifactor productivity comprised more than half of that increase. See Federal Reserve Bank of St. Louis (http://research.stlouisfed.org/fred2/series/OPHNFB) and BLS (http://www.bls.gov/mfp/tables.htm).

[24] A Bill Placing a Moratorium on the Cultivation of Genetically Engineered Organisms, Section 2: Findings, under *Cultural Heritage & Environmental Protection*, paragraph 1. Among other telling semantic manipulations, the bill defines transgenic introgression as transgenic "contamination" and identifies the phrase "genetically engineered" with "genetically modified" by way of common reference without noting that the former is but one technique for achieving the latter. See http://www.mauicounty.gov/ArchiveCenter/ViewFile/Item/19197.

[25] Global petroleum price shocks in the 1970s and, possibly, again during the last decade, may be responsible for a large portion of temporary but secular slowdowns in productivity growth on each occasion. These occasions also coincided with two notable (opposing) demographic events: entry of the Baby Boom cohort into the U.S. labor force in the 1970s, and early retirement of the same cohort in the 20-teens. See Kevin J. Stiroh (December 2002) "Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?" *American Economic Review* **92**:5 pp. 1559-76 (http://www.newyorkfed.org/research/staff_reports/sr115.html), and also William Nordhaus (May 6, 2014), "A Retrospective on the Postwar Productivity Slowdown" *processed*, Yale University.

[26] The compound annual growth rate of productivity, calculated as the annualized change in output per hour of U.S. private business between 1947 and 2012, was 2.18 percent. See Federal Reserve Bank of St. Louis (http://research.stlouisfed.org/fred2/series/OPHNFB) and BLS (http://www.bls.gov/mfp/tables.htm).

[27] Roughly since the introduction of the Apple IIe and IBM personal computers.

[28] Agricultural multi-factor productivity grew at a 1.43 percent annualized rate between 1948 and 2011. See USDA (http://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us.aspx#28268).

[29] Other contributions doubtless have been made through improved operational techniques, process change informed by information technology, and economies of scale and scope.

[30] The data precede the most dramatic changes in petroleum prices and those of biofuel substitutes, but the literature routinely includes feedback loops from grains to energy commodity stocks. See Graham Brookes, Tun Hsiang

“Edward” Yu, Simia Tokgoz, Amani Elobeid (2010), “The Production and Price Impact of Biotech Corn, Canola, and Soybean Crops,” *AgBioForum* **13**:1, pp. 25-52, and references therein.

[31] Corn, rice, wheat, barley, rye, sorghum, and a legume, soybeans.

[32] Nico Voigtländer and Hans-Joachim Voth (2013), “Gifts of Mars: Warfare and Europe’s Early Rise to Riches,” *Journal of Economic Perspectives* **27**:4, pp. 165-186. As suggested by Voigtländer and Voth:

> *The world prior to the Industrial Revolution was largely governed by Malthusian forces: that is, higher wages caused population growth to accelerate; higher population pressure reduced incomes. ...In a Malthusian world, neither technological advances nor improvements in institutions can lead to sustained increases in per capita output. A high rate of technological change in the premodern era was 0.25-0.50 percent annually...while the average was about 0.1 percent annually.*
>
> *On the other hand, human populations can easily expand at an annual rate of 3 percent or more. ...In other words, in a Malthusian economy the race between technology and population size is the turtle against the hare—technological change can almost never rise fast enough to overcome the deleterious effects of population growth. The same logic applies for institutional improvements. They, too, can improve the mapping from resources to output, just like technological advances—but it is highly unlikely that institutional improvements outpaced the ability of human populations to grow.*

[33] Voigtländer and Voth (2013) (see endnote 32) cite two contrasting experiences during most of the last millennium. In politically-unified China, absent wars and conflicts prone to incite epidemic contagion, Malthusian effects capped an agrarian population to about $600 a year in annual per capita income (in 1990 dollars). In contrast, following the depopulation of the Black Death (1348), politically and religiously fragmented Europe fought wars more than any other continent in recorded history. An average of 27 European wars occupied 89 percent of the years in each of the 16th–18th centuries. Wars caused epidemic disease outbreaks, periodically drawing down the population, yielding Malthusian “dividends:” fewer persons per unit of arable land. Marginal lands remained untapped, while urbanization (the need for fortification) further enhanced agricultural productivity. Europe thus prospered, relative to China, prior to the Industrial Revolution. The authors cite the data below from Angus Maddison (2007), *Contours of the World Economy 1-2030 AD: Essays in Macro-Economic History*, Oxford University Press.

	Urbanization rate (%)†		**Per capita GDP**‡	
*Year**	China	Europe	China	Europe
1000	3.0	0.0	$ 450	$ 422
1300			$ 600	$ 576
1500	3.8	5.6		
1700	4.0	8.3	$ 600	$ 924
1820	3.8	10.0	$ 600	$ 1,090

* Approximate
† Percentage of population living in cities >10,000
‡ In 1990 international dollars

[34] Voigtländer and Voth (2013), *op. cit.* p. 169.

[35] Hawaii median crude birth and death rates declined from 26 births and 42 deaths per thousand (1845-1885), to 26 births and 15 deaths per thousand (1900-1930), to 27.7 births and 5.6 deaths per thousand (1945-1965), and most recently to 14.3 births and 7.0 deaths per thousand (1995-2013). Compare the latter 0.7 percent population growth rate (excluding net migration) to overall productivity growth of 2.3 percent, or to agricultural multi-factor productivity growth of 1.4 percent since 1995.

[36] David Autor (2010), “U.S. Labor Market Challenges over the Longer Term,” *processed*, MIT Department of Economics and NBER (http://economics.mit.edu/files/6341).

[37] See Tables 4.4 Robert C. Schmitt, *Historical Statistics of Hawaii* (1976), University of Hawaii Press, and Hawaii Department of Labor and Industrial Relations (https://www.hiwi.org/gsipub/index.asp?docid=421).

[38] Joseph Schumpeter (1942), *Capitalism, Socialism and Democracy*. New York: Harper.

[39] Losers in the last four decades include sales, office, production, repair, and craft workers, as well as operators, fabricators, and laborers. Professional and technical workers' opportunities have grown, as have those of services occupations involving helping, caring for, or assisting other people. For example, food services employment has been one of the fastest growing sectors in Hawaii during the 21st century. Polarization is a demand-side force in the labor market. It is partly offset by a supply-side force in which rising female educational attainment and stagnating male educational attainment during the last forty years has led to a U.S. labor market that greatly rewards higher educational attainment but absolutely penalizes males who finished or did not finish high school, relative to their own counterparts a generation ago.

[40] See James J. Heckman (2008), "Schools, Skills, and Synapses," *Economic Inquiry* **46**:3 pp. 289-324 (http://www.nber.org/papers/w14064.pdf).

[41] Data are from the Bureau of Economic Analysis, U.S. Department of Commerce. Care should be taken in interpreting the comparisons because the older data define industries on an SIC basis (in terms of "output"), while the newer data define industries on an NAICS basis (in terms of "activities"). For example, printing and publishing used to be a manufacturing industry because of its final output, but today it is an information activity. The private sector has grown, relative to the public sector. In 1963, federal military (13.2 percent of GDP), federal civilian (9.4 percent), and state and local government (7.1) collectively comprised 29.7 percent of Hawaii GDP. In 2012, government was 22.4 percent of Hawaii GDP; the 2011 military share was 7.9 percent, federal civilian government was 5.6 percent, and state and local government 9.4 percent of Hawaii GDP (government sector details for 2013 are not yet available). Private, financial services increased from 15.5 percent to 24.4 percent of Hawaii GDP in the half century between 1963 and 2013.

[42] See James Mak (2005), "Tourism demand and output in the U.S. Tourism Satellite Accounts: 1998-2003," *Journal of Travel Research*, **44** (1), pp. 4-5, Eugene Tian, James Mak, and PingSun Leung (2011), "The direct and indirect contributions of tourism to regional GDP: Hawaii," *UHERO Working Paper No. 2011-5* (http://www.uhero.hawaii.edu/assets/WP_2011-5.pdf), and DBEDT World Travel and Tourism Council report (http://hawaii.gov/dbedt/info/visitor-stats/econ-impact/WTTC99.pdf).

[43] Using the Honolulu Consumer Price Index for All Urban Consumers (CPI-U) as deflator, total Hawaii visitor expenditure (tourism receipts) in 1989 reached an all-time high of $17.52 billion. In 2013, real visitor expenditure was $14.50 billion, essentially matching 2007 receipts of $14.51 billion in the final year of U.S. economic expansion before the Great Recession (which began in December 2007), both in 2013 dollars. Real visitor expenditure's low point during the last quarter century was at the end of that recession, in 2009, at $10.87 billion (in 2013 dollars), the same as in 1984 ($10.871 billion, in 2013 dollars).