

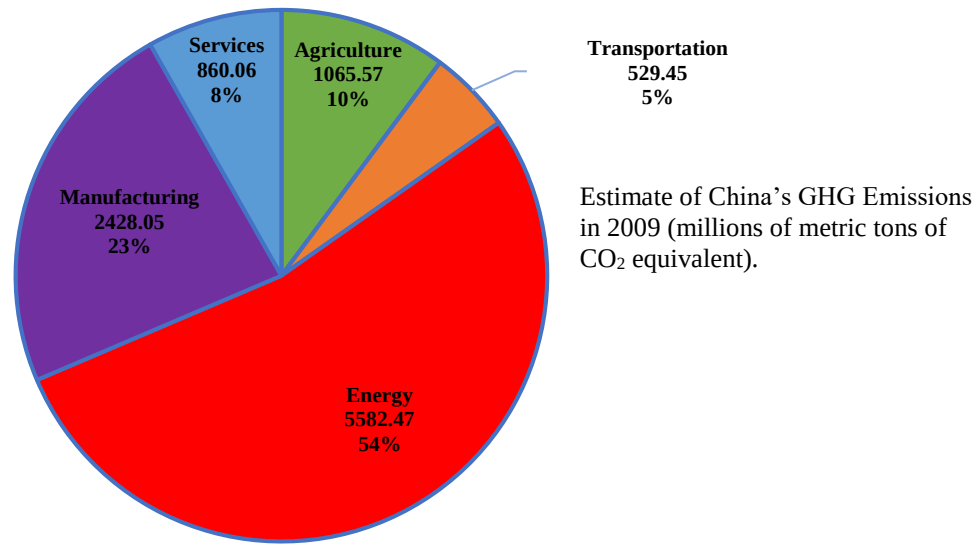
I. Introduction

This paper examines the environmental and economic impacts in 2030 of the recently revised People's Republic of China's national dietary guidelines. In 2016, the publication of these guidelines attracted widespread media attention for their potential to help mitigate the worst effects of climate change due to their recommendation that citizens of the People's Republic of China (China) eat less meat. Effective and efficient climate change policies are increasingly necessary and important given the short window of time remaining to avoid climate catastrophe. China bears an especially large burden in enacting these policies given its large population and rapidly developing economy. Globally, the agricultural sector is a significant contributor to global GHG emissions, making up between 13% and 25% of total anthropogenic emissions according to various estimations (World Resources Institute 2019; Vermuelen et al. 2012).

In China, the agricultural sector accounts for approximately 10% of GHG emissions (figure 1). Furthermore, food production is one sector of the economy in which the availability of emissions-reducing technological solutions are relatively limited. For these reasons, much attention should be given to China's national dietary guidelines as a potential policy tool for mitigating the worst effects of climate change. This analysis finds that China's current national dietary guidelines have a negligible impact on GHG emissions in 2030, despite its targeted decline in meat consumption, due to the guidelines' recommendation to increase dairy consumption. Overall, China's national dietary guidelines are projected to decrease global GHG emissions in 2030 by 0.04%, or 28.01 million metric tons of CO₂ equivalent. Within the global agricultural sector, China's national dietary guidelines are projected to increase GHG emissions in 2030 by 0.49%, or 29.57 million metric tons of CO₂ equivalent.

The analysis uses the GTAP CGE model to project the global economy to 2030 under a baseline scenario and a scenario in which China fully implements its national recommended diet, hereafter referred to as the Food Pagoda policy. Environmental and economic effects of the Food Pagoda policy are estimated as the differences between these two projected scenarios. The use of GTAP, a computable general equilibrium model, allows the analysis to estimate the global impact of the Food Pagoda policy in 2030, not just the national impact. This ensures that emissions leakages across countries are accounted for.¹

Figure 1



Sources: GTAP 9 database (2009), GTAP CO₂ Emissions database (2009), and GTAP Non-CO₂ Emissions database (2011).

¹ For a literature review of how other studies have estimated the environmental effect of Chinese diets, please see Appendix 1.

II. Data and Methodology

i. CGE Model and Database

This analysis employs the GTAP CGE model to project the global economy to 2030 under a baseline scenario and a scenario in which China fully implements its Food Pagoda policy. The model contains seven regions (China, United States, EU28, Russia, Brazil, Mexico, and “Rest of World”). The regional aggregation is determined based on the five countries (other than China) with the highest total meat consumption levels according to the OECD (2019). The model defines 24 sectors, of which 16 are food and agriculture, and three factors of production: capital, labor, and land. We assume the standard GTAP closures, but allocate global investment across regions based on their fixed initial investment shares. The model uses the 2009 GTAP database.

Table 1

	Scenarios
Baseline	Projections of global economy to 2030 with projected China food demand by Sheng and Song (2018)
Food Pagoda	Projections of global economy to 2030 with projected China food demand per China’s Food Pagoda policy (2016)

ii. GHG Emissions Data

GHGs are gasses that contribute to climate change by trapping heat in the Earth’s atmosphere and that persist therein for a significant period of time. Emissions data for this analysis comes from two sources included in the GTAP 9 database. The GTAP CO₂ Emissions database reports the metric tons of CO₂ emitted by fuel consumption in each sector and region of the GTAP model for the base year (2009). The 2009 GHG emissions data from this database are applied to the results for quantity of output (qo) from the Baseline and Food Pagoda scenarios to estimate their associated CO₂ emissions in 2030.

The GTAP Non-CO₂ Emissions database supplements this data by reporting the metric tons of CO₂ equivalent emitted throughout the production and consumption processes in each sector and region of the GTAP model for the year 2011. The GHGs whose emissions are estimated in this database include methane (CH₄), nitrous oxide (N₂O), and F-gasses (HFCs, PFCs and SF₆). The database provides non-CO₂ emissions for each sector and region of the model, and sub-categorizes them as coming from output, input use by industry, consumption, or factors of production. To estimate the non-CO₂ emissions from the Baseline and Food Pagoda scenarios, the GHG emissions coming from output and input use by industry are applied to the results for quantity of output (qo); the GHG emissions coming from consumption are applied to results for quantity of composite household demand (qp); and the GHG emissions coming from factors of production are applied to results for quantity of endowments (qfe).

iii. Scenarios, 2030 Projections Data, and Dietary Data

Two scenarios are developed to estimate the environmental and economic impact of the Food Pagoda policy (table 1). Both are projections of the global economy to 2030 but differ in consumer dietary preferences. To create the scenarios, supplementary data are used for projected 2030 values of populations, capital stocks, labor supplies, land supplies, and real GDP for each region in the model. Population and GDP values are drawn from SSP2v9 scenario of the IIASA GDP database (KC and Lutz 2017; Cuaresma 2017); capital stocks and labor supplies are drawn from Fouré, *et al* (2012); and land supplies are drawn from Alexandratos and Bruinsma (2012). These projected values are first applied as shocks to a GTAP model with GDP made exogenous and total factor productivity made endogenous, yielding a total productivity growth rate value for each region. The total factor productivity growth rates are then inputted in place of the GDP values, returning GDP to a status of endogeneity.

Consumer preferences in GTAP are described by a constant difference of elasticities (CDE) demand system, and determined by substitution and income parameters. There is no direct way to change consumer preferences in the GTAP model. Our approach is to describe changes in consumer preferences by adjusting the income parameters in each scenario for the relevant commodities (fruits and vegetables, ruminant products, other animal products, processed rice, vegetable oils and fats, and dairy products) so that household food consumption reflects projected diets as incomes grow over time.²

In the first scenario, called the “Baseline” scenario, the income parameters for fruits and vegetables, ruminant products, other animal products, processed rice, vegetable oil and fats, and dairy are altered (table 2) to target China’s food consumption projections in 2030 from Sheng and Song (2018) (figure 2). Specifically, these commodities’ income parameters are adjusted until the percent change in their consumption levels from 2009-2030 in the baseline scenario are equal to the percent change in their consumption levels described by Sheng’s and Song’s projections. In other words, major food types’ consumption growth rates between 2009-2030 are taken from Sheng and Song (2018), and applied to the GTAP model by altering consumers’ income parameters.

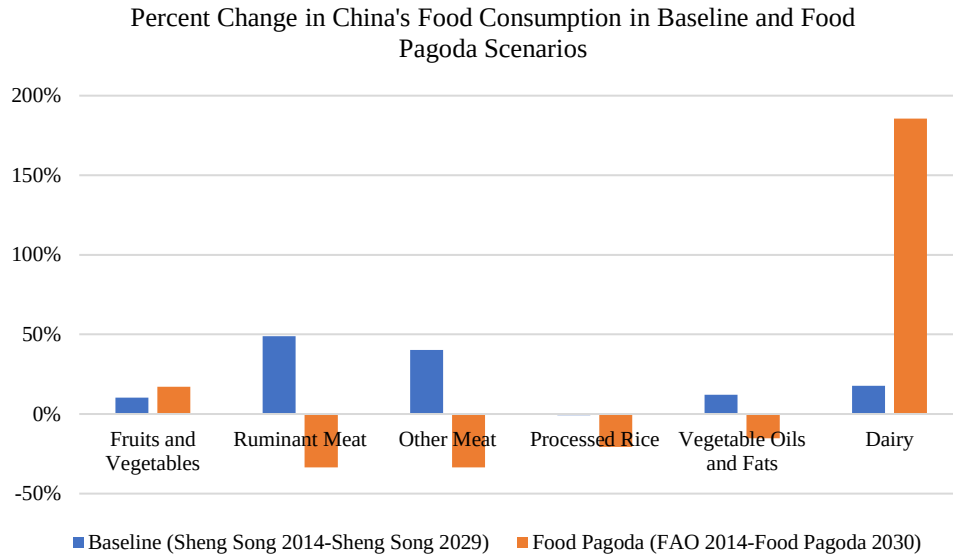
In the second scenario, called the “Food Pagoda” scenario, the same set of income parameters are altered to target PRC food consumption levels in 2030 according to the Food Pagoda policy. The percent changes in China’s food consumption in the Food Pagoda scenario are calculated using FAO statistics on per capita Chinese food consumption from 2009 and the Food Pagoda recommendations. To convert the per-capita values to absolute values, the data were multiplied by the IIASA-estimated population of China for 2009 and 2030, respectively. Both sets of consumption data are converted into calories using FAO gram/calories conversion rates. Per capita caloric intake is held constant (to the Food Pagoda consumption levels) in order to show the impact of changes in dietary composition rather than change in overall caloric intake, and to prevent per capita caloric intake from dropping below realistic levels as a result of discrepancies between the absolute caloric intake values from the FAO statistics and the Food Pagoda policy.

Table 2

INCPARs	Fruits and Vegetables	Ruminant Meat	Other Meat	Processed Rice	Vegetable Oils and Fats	Dairy
Baseline	-0.02	0.20	0.10	-0.26	-0.25	-0.22
Food Pagoda	0.08	-1.43	-1.42	0.63	-0.78	1.60

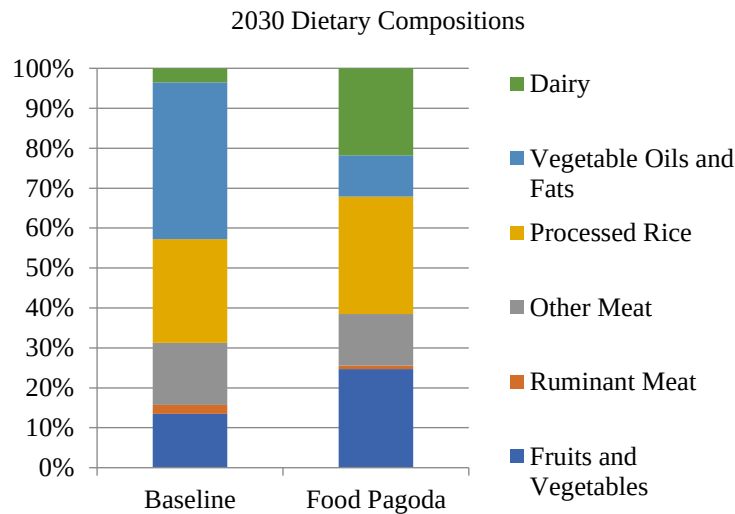
Figure 2

² For a literature review of how consumer preferences may be changed in CGE models, please see Appendix 2.



Dietary composition in 2030 is different for each scenario (figure 3) as a result of the two scenarios' different growth rates for food consumption levels between 2009-2030. The Baseline scenario's 2030 diet is high in vegetable oils and fats, processed rice, and meat. The baseline trend is consistent with the studies of the current dietary trend in China, which show that packaged foods and beverages made up 29.6% of all calories consumed in 2014, and that foods are increasingly fried rather than baked, boiled, or steamed (Popkin 2014; Zhai et al. 2014). The Food Pagoda policy is primarily an effort to mitigate expensive and widespread health issues associated with the current dietary trend, and the Food Pagoda scenario 2030 diet is therefore made up of less meat, less vegetable oils and fats, more processed rice, and more fruits and vegetables. However, another important feature of the Food Pagoda scenario's 2030 diet, especially in terms of its emissions impact, is the 22% share occupied by dairy (versus just 4% in the Baseline scenario 2030 diet).

Figure 3



III. Results

The direct impact of the Food Pagoda policy is a 1.7% increase (22.34 million metric tons of CO₂ equivalent) in China's agricultural emissions in 2030 relative to the Baseline scenario. This net increase in agricultural emissions in the Food Pagoda scenario is attributed to an increase in GHG emissions from the dairy

sector (mostly from an increase in its use of ruminant animals), which is slightly offset by a decrease in GHG emissions from the rice and other livestock (non-ruminant animals and non-ruminant animal products) sectors. In 2030, GHG Emissions in China’s dairy sector in the Food Pagoda scenario are 111% greater than they are in the Baseline scenario (figure 5), reflecting the dramatic increase in dairy’s share in per capita caloric consumption under the Food Pagoda policy. In absolute terms, 2030 GHG emissions from the dairy sector increase by 43.74 million metric tons of CO₂ equivalent (figure 6) as a result of the Food Pagoda policy. The consumption of other emissions-intensive commodities (rice, ruminants, and other livestock) do not decrease enough under the Food Pagoda policy to have a significant overall impact on China’s agricultural GHG emissions.

Figure 5

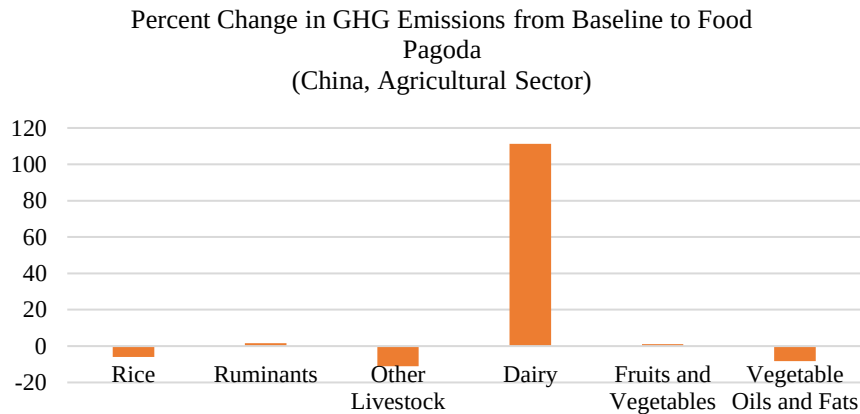
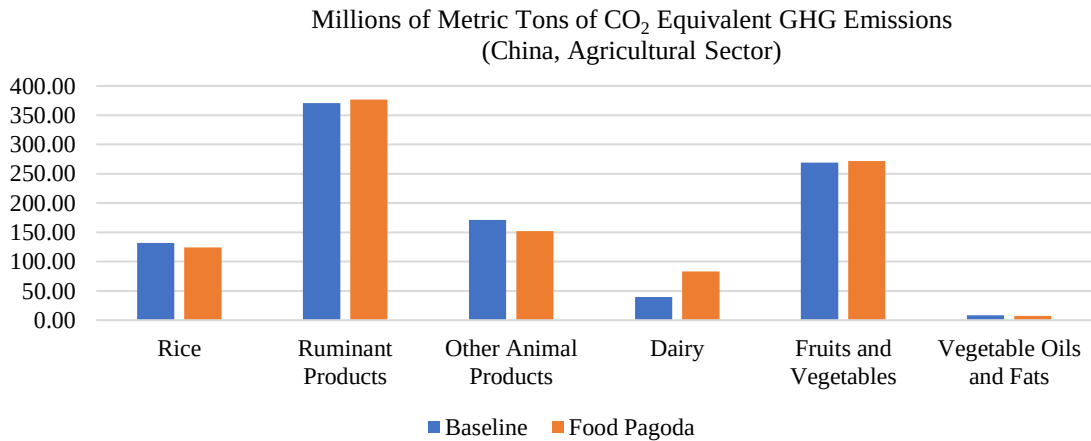


Figure 6



China’s Food Pagoda policy decreases China’s overall GHG emissions in 2030 relative to the Baseline scenario, but only by 0.16%, or 28.74 million metric tons of CO₂ equivalent. Between the two scenarios, there is little variation within any given sector in either relative terms (figure 7) or absolute terms (figure 8). The largest absolute change occurs in the energy sector (-58.93 million metric tons of CO₂ equivalent). This change occurs as a result of a small fall in the quantity of composite household demand for utilities and energy in the Food Pagoda scenario. Other than agriculture, manufacturing is the only sector whose 2030 GHG emissions increase as a result of the Food Pagoda policy, compared to the baseline scenario. This is the result of slight relative increases in the quantity of output in the emissions-intensive manufacturing and mineral production sectors.

Figure 7

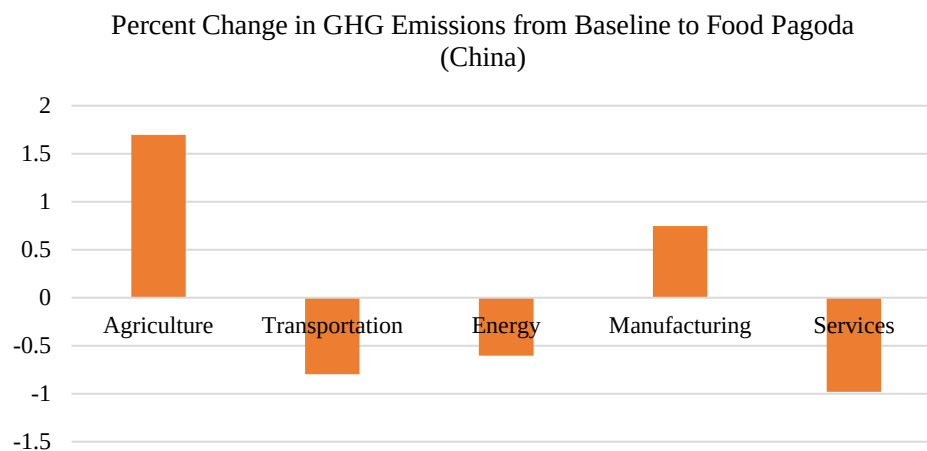
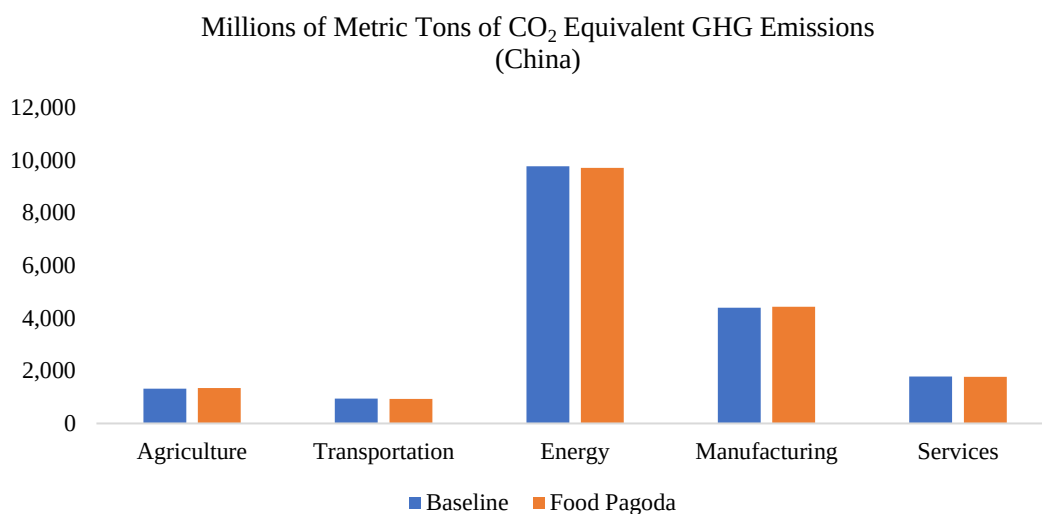


Figure 8



Global, economywide GHG emissions in 2030 are 0.04% lower in the Food Pagoda scenario relative to the Baseline scenario. This 28.01 million metric tons of CO₂ equivalent difference is due to small (less than 0.3%), declines in GHG emissions across every sector except manufacturing (figure 9), relative to the baseline, and is predominantly due to the previously examined changes in China's economy. This is an important finding, in that it suggests that there would be extremely limited "carbon leakage" effects from the Food Pagoda policy – wherein changes in GHG emissions in a country enacting a policy are offset by other countries without that policy.

Figure 9

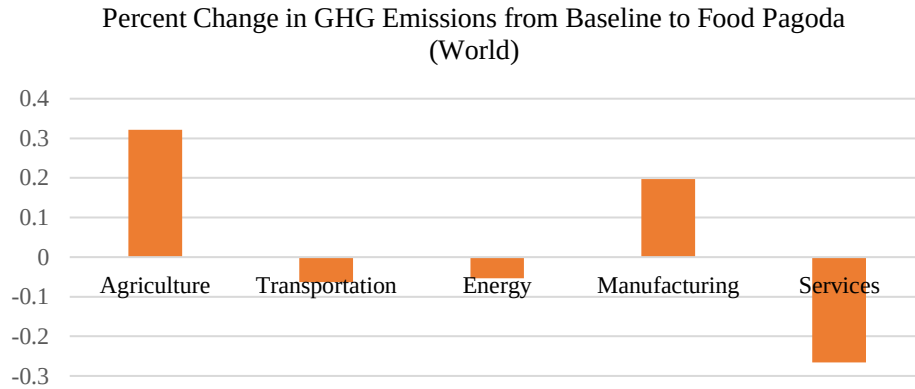
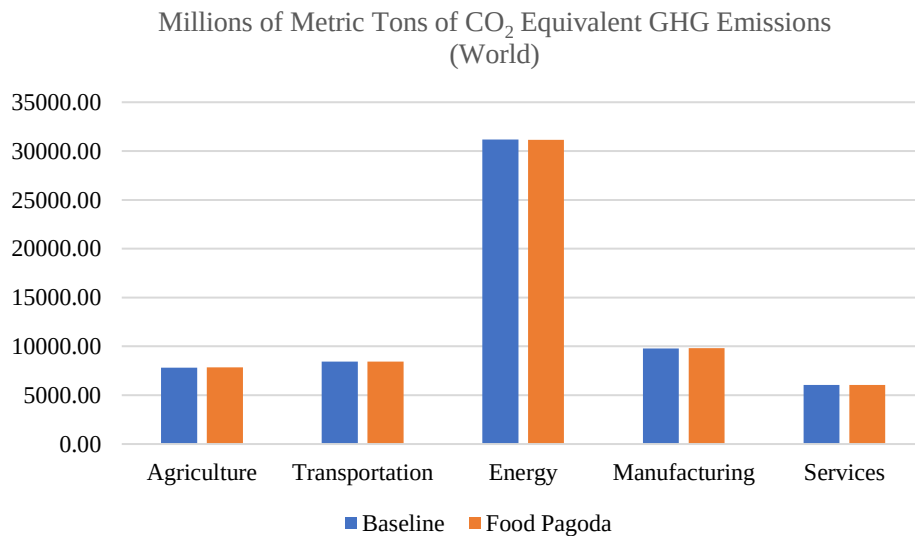


Figure 10



VI. Conclusion

This paper provides an analysis of the environmental and economic impact of China's national dietary guidelines using a GTAP CGE model. In 2030, Chinese agricultural emissions are projected to increase by 22.34 million metric tons of CO₂ equivalent as a result of the dietary guidelines, assuming they are fully adopted. This increase in GHG emissions is largely due to the guidelines' recommendation that Chinese citizens consume a greater quantity of emissions-intensive dairy products. However, the analysis also finds that household demand for even more emissions-intensive commodities (energy and utilities) declines as an indirect result of the national dietary guidelines. Subsequently, China's overall GHG emissions are projected to decline by 28.01 million metric tons of CO₂ equivalent as a result of the dietary guidelines. Finally, the analysis determines that China's dietary guidelines have very little impact on the structure or volume of GHG emissions in other countries.

Appendix 1

Literature Review for Modelling the Impact of the Food Pagoda Policy					
Author(s)	Research question	Model	Scenario(s)	Results	Source of consumption data
Jacobs, Henry (2019)	What are the direct and indirect effects of the Chinese Food Pagoda policy?	Computable general equilibrium model (GTAP)	Holding calories constant, comparison of Food Pagoda diet with trend Sheng and Song (2018) projections	Agricultural and economywide GHG emissions in 2030 increase slightly as a result of the Food Pagoda policy	FAOSTAT, Sheng and Song (2018), and Chinese Nutrition Society (2016)
Li, Huimin, Tong Wu, Xiao Wang, and Ye Qi (2016)	What is the GHG footprint of China's food chain system and how might China transition to a low carbon system?	Multiregional life cycle analysis	Comparison of trend, technology improvement scenario, and combined healthier diet and technology improvement scenario	GHG emissions increase dramatically in trend scenario, decrease modestly in technology scenario, and decrease dramatically in combined scenario	Chinese Nutrition Society (2010)
He, Pan, Giovanni Baiocchi, Klaus Hubacek, Kuishuang Feng, and Yang Yu (2018)	What are the nutritional and environmental impacts of observed changes in Chinese diets between 1997 and 2011?	Life cycle analysis	Observed diets of 21,500 individuals living in China between 1997-2011	GHG emissions increased over the period 1997-2011 due to increased consumption of non-starchy foods	China Health and Nutrition Survey (1997-2011)
Behrens, Paul, Jessica C. Kiefte-de Jong, Thijs Bosker, João F. D. Rodrigues, Arjan de Koning, and Arnold Tukker (2017)	What are the environmental impacts of average dietary intakes and nation-specific recommended diets?	Life cycle analysis	Comparison of average national diets to national recommended diets	GHG emissions for China increase as a result of switching to the national recommended diet	FAOSTAT

Appendix 2

Literature Review for Modelling Consumer Preferences in a CGE Model				
Authors	Research question	CGE Model	Scenario(s)	How change in consumer preferences was modelled
Jacobs, Henry (2019)	What are the direct and indirect effects of projected changes in Chinese diet?	Standard CGE model in GTAP	Holding calories constant, comparison of Food Pagoda scenario with trend scenario	Adjusted income demand parameter (Engel curve approach) as economies grow over 2009-2030
Vanzetti, David, Nur Rakhman, and Rina Oktaviani (2013)	What is the impact of a campaign to increase consumption of domestic milk in Indonesia?	Standard CGE model in GTAP	Fresh milk campaign, increase in number of cows, productivity increase, and trade liberalization	Introduced consumption tax to bring about desired change in consumption of domestic dairy products
Nielsen, Chantal Pohl, Karen Thierfelder, and Sherman Robinson (2003)	What is the impact of changes in consumer attitudes towards genetically modified food?	Standard CGE model	Comparing the effects of changing factor productivity for genetically modified commodities within a high constant elasticity of substitution scenario and low constant elasticity of substitution scenario	Segmented agricultural sectors affected by genetic modification and created a constant elasticity of substitution function to represent consumer choice between genetically modified and non-genetically modified products
Diao, Xinshen (2009)	What is the economywide impact of highly pathogenic avian influenza in Ghana under different scenarios?	Dynamic CGE model in GAMS	Baseline scenario; three scenarios in which chicken production is reduced for 2009, 2009-2010, and 2009-2011; and three scenarios in which chicken demand is also reduced for 2009, 2009-2010, and 2009-2011	Changed the marginal budget share for chicken in the Stone-Geary demand function

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