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Health and Greenhouse Gas Emission Implications of Reducing Meat Intakes in Hong Kong

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***Abstract*—**High meat and especially red meat intakes are significantly and positively associated with a multiple burden of diseases and also high greenhouse gas (GHG) emissions. This study investigated population meat intake patterns in Hong Kong. It quantified the burden of disease and GHG emission outcomes by modeling to adjust Hong Kong population meat intakes to recommended healthy levels. It compared age- and sex-specific population meat, fruit and vegetable intakes obtained from a population survey among adults aged 20 years and over in Hong Kong in 2005-2007, against intake recommendations suggested in the Modelling System to Inform the Revision of the Australian Guide to Healthy Eating (AGHE-2011-MS) technical document. This study found that meat and meat alternatives, especially red meat intakes among Hong Kong males aged 20+ years and over are significantly higher than recommended. Red meat intakes among females aged 50-69 years and other meat and alternatives intakes among aged 20-59 years are also higher than recommended. Taking the 2005-07 age- and sex-specific population meat intake as baselines, three counterfactual scenarios of adjusting Hong Kong adult population meat intakes to AGHE-2011-MS and Pre-2011 AGHE recommendations by the year 2030 were established. Consequent energy intake gaps were substituted with additional legume, fruit and vegetable intakes. To quantify the consequent GHG emission outcomes associated with Hong Kong meat intakes, Cradle-to-ready-to-eat lifecycle assessment emission outcome modelling was used. Comparative risk assessment of burden of disease model was used to quantify the health outcomes. This study found adjusting meat intakes to recommended levels could reduce Hong Kong GHG emission by 17%-44% when compared against baseline meat intake emissions, and prevent 2,519 to 7,012 premature deaths in males and 53 to 1,342 in females, as well as multiple burden of diseases when compared to the baseline meat intake scenario. Comparing lump sum meat intake reduction and outcome measures across the entire population, and using emission factors, and relative risks from individual studies in previous co-benefit studies, this study used age- and sex-specific input and output measures, emission factors and relative risks obtained from high quality meta-analysis and meta-review respectively, and has taken government dietary recommendations into account. Hence evaluations in this study are of better quality and more reflective of real life practices. Further to previous co-benefit studies, this study pinpointed age- and sex-specific population and meat-type-specific intervention points and leverages. When compared with similar studies in Australia, this study also showed that intervention points and leverages among populations in different geographic and cultural background could be different, and that globalization also globalizes meat consumption emission effects. More regional and cultural specific evaluations are recommended to promote more sustainable meat consumption and enhance global food security.

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I. Introduction

CANCER and cardiovascular diseases (CVD) are the top two leading cause of deaths in Hong Kong, while diabetes is in the top 10. In 2014, cancer accounted for 13,803 deaths, 30% of total deaths; heart and cerebrovascular diseases accounted for a total of 9,741 deaths, 21% of total deaths and; diabetes accounted for 390 deaths and about 1% of total deaths [1]. Epidemiological evidence showed that high meat intakes, and especially high red and processed meat intake, are significantly associated with these burden of diseases [2]. High meat intakes are also associated with increased risk of hypertension and obesity [3], [4], which damages arteries, heart, brain and kidney. Diabetes, hypertension and obesity are risk factors for CVD. Red meat intake is blamed for significantly higher GHG emission when compared to other meat and plant-based food [5]. Conversely, per capita meat consumption (meat supply for consumption at the commodity level) in Hong Kong is much higher than in leading meat consumption countries at 432 g/capita/day in Hong Kong in 2012 compared to 348 and 332 g/capita/day, respectively, in New Zealand in 2012 and Australia in 2011 [6]. Per capita per day meat consumption in Hong Kong is also increasing more rapidly, by 29%, from 334 g/capita/day in 1995 to 432 g/capita/day in 2012. A high proportion of meat consumed in Hong Kong come from high GHG emission red meat (60%, 259 g/capita/day, about 54g more than in Australia) which poses higher risk of chronic diseases when compared to poultry meat [2].

A prospective cohort study of 134,000 Chinese adults found that greater compliance with dietary guidelines reduces mortality [7]. It is estimated that adjusting Australian meat intake to government recommended levels and substituting fruit and vegetable to account for the reduced energy intake could reduce a list of 17 burden of diseases, and especially all-cause and CVD mortalities; stroke, and lung cancer risks [8], as well as reduce GHG emission by 24% to 58% when compared to baseline meat intake emissions [9]. This study investigated Hong Kong population meat, fruit and vegetable intake patterns and quantified burden of disease and GHG emission outcomes from adjusting Hong Kong adult population meat intakes to Australian government recommended levels by substituting fruit and vegetables to compensate for the reduced energy intake.

II. Methods

A. Meat Definitions

Red meat: meat derived from bovine, ovine, pig, and other mammalian game.

Processed meat: meat products having a minimum of 30% meat that has undergone a method of processing other than boning, slicing, dicing, mincing or freezing [10]. Including meat which has been salted, smoked, cured or fermented such as hot dogs, hams, sausages and biltong.

Total meat: includes poultry and red meat.

Meat and alternatives: includes poultry and red meat, as well as fish, seafood, and egg products. Also, including nuts in the case of Hong Kong and Australian pre-2011 government recommendations.

B. Population Meat, Legume, Fruit and Vegetable Intake Gaps

Population dietary food intakes: age- and sex-specific adult population meat, legume, fruit and vegetable intake patterns were derived from the most up to date Hong Kong Population-based Food Consumption Survey database conducted and compiled in 2005-2007 (FCS 2005-2007). FCS 2005-2007 collected dietary intake data comprising two non-consecutive 24-hour recall assessments from 5,008 adults aged 20 years to 80 years, selected using age- and sex-quota sampling methods.

Age- and sex-specific dietary guidelines: The World Cancer Research Fund International (WCRFI) recommends taking no or very little if any processed meat, and less than 61g of red meat per day [11]. The Dietary Guidelines for Americans [12] recommend about 51 g red meat per day, whereas the Eatwell Plate, UK recommended less than 70g [13]. The Hong Kong Government acknowledges different stages of life may have different dietary needs and provides specific health eating guidelines to children, as well as to adults, in the form of a Food Pyramid [14]. Its current recommendation is 189-302g total meat and meat alternatives intake per day per adult, consistent with recommendations in the Modelling System to Inform the Revision of the Australian Guide to Healthy Eating (AGHE-2011-MS) technical document [15]. Among all, the AGHE-2011-MS provides the most complimentary recommendations of the amount of food from each food group and more specific sub-groups including meat intakes by red meats and meat and alternatives minus red meat, as well as weekly individual needs for different age, sex, lifestyle, body size and activity which the Hong Kong Food Pyramid does not provide. Therefore, recommendations in the Australian Guide to Healthy Eating were used in this study.

Age- and sex-specific population dietary gaps: meat, legume fruit and vegetable intake gaps were derived by comparing the age- and sex-specific intake levels obtained from FCS 2005-07 against the minimum recommendations in the Total Diets samples for each population sub-group in AGHE-2011-MS (used as recommended levels in his study).

C. Baseline and Counterfactual Scenarios by 2030

It was assumed that by 2030, the age- and sex-specific baseline circumstances would be otherwise held constant as at the 2005-2007 conditions. Three age- and sex-specific meat, fruit and vegetable intake counterfactual scenarios for the general population (excluding pregnancy) in 2030 were established based on the population projection in 2030 [16], and according to the following principles that:

1. Assumed total energy intakes were unchanged and energy balance was achieved through dietary shift between meat, fruit and vegetable.
2. Assumed fish, seafood, egg and nut product intakes remained unchanged, and keeping one serving of processed meat intake per week, or at current level if current intake is less than one serving per week.
3. Scenario S1: Adjusted meat intakes as recommended in AGHE-2011-MS, and kept at least one serving of each bovine, ovine, and poultry meat per week, or if current intake is less than one serving per week then kept current intake. Shift recommended red meat gap to pork.
4. Scenario S2: Adjusted total meat and alternatives intakes as recommended in AGHE-2011-MS. Kept at least one serving of bovine meat and a total of three servings of red meat per week. Shift recommended red meat gap to poultry meat.
5. Scenario S3: Kept meat and alternatives, minus red meat intakes, at least as recommended in AGHE-2011-MS. Kept at least one serving of each poultry and bovine meat, and a total of three servings of red meat. Shift recommended red meat gap to legume.
6. Subsequent energy reduction gaps were substituted in order with legumes, fruit, and vegetable recommendations.

D. Scenario GHG Emission Outcome Evaluations

Cradle-to-ready-to-eat GHG emission outcome evaluation modelling, extensively described in [9], was used to quantify related GHG emission changes. Mean Cradle-to-ready-to-eat food group GHG emission factors (Table V) were obtained from a high quality systematic review of 921 lifecycle assessments of 138 food product types from a total of 159 studies [5], using system boundaries that included GHG emissions from major cradle-to-farm-gate and post-farm activities up to ready-to-eat (in case of meat: cooked, bone off and excluded any inedible) at home/restaurants and adjusted to meat and cooking yields. As there is little food production in Hong Kong, most of the food products are imported. Therefore, emission outcomes were evaluated in import, global domestic and global contexts [5]. Due to the lack of data, baseline emission factors and estimation in import context were based on foods imported to the UK.

E. Scenario Health Outcome Evaluations

Comparative Risk Assessment (CRA) of burden of disease model extensively described in [8] was used to estimate the burden of diseases attributable to changes in exposure distributions of meat, fruit and vegetable intakes in 2030. Risk factors of each disease outcome measure, and dose response relative risk at 95% confidence level of each disease-specific risk factor (Table VI) were obtained from a high quality Meta-

review of burden of diseases associated with meat, fruit and vegetable intakes [2].

Age- and sex-specific all-causes, CVD and cancer mortality, CHD, stroke, and diabetes II inpatient discharges and deaths crude rates in 2014 obtained from the Hong Kong Department of Health, and cancer incidence crude rates in 2013 obtained from the Hong Kong Cancer Registry web site [17] were used as baselines. Additional assumptions included:

1. Age- and sex-specific dietary patterns are otherwise held constant as at 2005-2007 conditions.
2. Other health related baseline circumstances are otherwise held constant as at 2013 and 2014, accordingly.
3. An instantaneous implementation of the proposed scenario measures, with no other change.
4. Exposure distribution remained constant and the population attributable fraction (PAF) per 100,000 persons for meat, fruit and vegetable intakes remained as in 2013-2014 and unchanged with time.

F. Sensitivity Test

Sensitivity tests were carried out with the upper and low confidence intervals of the associated relative risks.

III. Results

A. Meat, Fruit, and Vegetable Intake Trends and Gaps

On average Hong Kong meat intakes among males is significantly higher than females (158g vs. 100g per capita per day, respectively) primarily in the form of red meat (109g vs. 65g capita per day, respectively). Red meat intakes among females approximate to recommended levels, except among those aged 50 years to 69 years, where higher than recommended (Table I), whereas meat and alternatives minus red meat intakes among those aged 20 years to 39 years are also high. Both red and other meat and alternatives minus red meat intakes among males aged 20 years to 49 years are significantly higher (almost double) those recommended, and among males aged 50+ years old are also high, except meat and alternatives, minus red meat intakes, among males aged 70+ years old. Higher proportions of meat and alternatives minus red meat intakes come from egg, fish and seafood instead of poultry meat. All fruit, vegetable and legume intakes among both males and females are significantly less than recommended. Of the sample size n=5,008, there is a significant but weak linear negative associated between total meat intake and total fruit and vegetable intake (Pearson Correlation R= -0.074, p<0.001).

TABLE I
COMPARISON OF HONG KONG MEAT FRUIT AND VEGETABLE INTAKES IN 2005-07 VS RECOMMENDED IN AGHE-2011-MS AND PRE-2011 AGHE

Age Group (years)		20-29	30-39	40-49	50-59	60-69	70+	20-29	30-39	40-49	50-59	60-69	70+
		Serving# per Capita per day											
		Male						Female					
Red meat	2005-07 Intakes	1.8	1.9	1.8	1.6	1.3	1.2	1.0	1.1	1.0	1.0	0.9	0.7
AGHE-2011-MS	Recommended	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.7	0.7
	Difference	0.8	0.9	0.8	0.6	0.3	0.2	0.0	0.1	0.0	0.3	0.2	0.0
Meat and alternatives minus red meat	2005-07 Intakes	2.1	2.0	1.8	1.5	1.1	1.0	1.3	1.3	1.1	1.0	0.8	0.6
AGHE-2011-MS	Recommended	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Difference	1.1	1.0	0.8	0.5	0.1	0.0	0.3	0.3	0.1	0.0	-0.2	-0.4
Total difference		1.9	1.9	1.5	1.1	0.4	0.2	0.4	0.4	0.1	0.4	0.0	-0.4
Meat and alternatives	2005-07 Intakes	4.1	4.0	3.6	3.2	2.5	2.3	2.4	2.5	2.2	2.1	1.7	1.4
Pre-2011 AGHE	Recommended	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Difference	3.1	3.0	2.6	2.2	1.5	1.3	1.4	1.5	1.2	1.1	0.7	0.4
Fruit	2005-07 Intakes	0.5	0.7	1.0	1.1	1.2	1.1	0.7	1.0	1.2	1.3	1.2	1.1
AGHE-2011-MS	Recommended	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Difference	-1.5	-1.3	-1.0	-0.9	-0.8	-0.9	-1.3	-1.0	-0.8	-0.7	-0.8	-0.9
Vegetables	2005-07 Intakes	1.6	1.9	2.2	2.7	3.1	2.7	1.8	2.3	2.6	2.7	3.0	2.7
AGHE-2011-MS	Recommended	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	Difference	-2.4	-2.1	-1.8	-1.3	-0.9	-1.3	-2.2	-1.7	-1.4	-1.3	-1.0	-1.3
Legume	2005-07 Intakes	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2
AGHE-2011-MS	Recommended	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Difference	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.9	-0.8	-0.8	-0.8	-0.8	-0.8

refer to [15] for food serving sizes

B. Counterfactual Intake Scenario Adjustments and Emission Outcomes

To meet the AGHE-2011-MS intake recommendations, in scenario S1 reductions of 36% and 11% in red meat intakes were recommended among males and females, respectively (Table II). Total meat and alternatives intakes exceed the Pre-2011 AGHE recommendation in all scenarios. As the baseline fruit and vegetable intakes are significantly below recommendations, outcome fruit and vegetable intakes do not exceed the AGHE-2011-MS recommendations in all scenarios. The model estimated that meat intakes among Hong Kong males aged 20+ years old contributed 4.2 $kgCO_2$-e emission per capita per day, almost double that of females at 2.3 $kgCO_2$-e. Most of such emissions (about 90%) come from red meat intakes. If the meat intake patterns remain unchanged then total annual meat intake-related GHG emissions among

Hong Kong adults aged 20+ years old would increase to 7,752ktCO_2-e by 2030. However, adjusting meat intakes to the AGHE-2011-MS recommended levels as in scenario S1 results in reductions of such emissions by 17%; the emission reduction could increase to 38% if substituting part of the recommended red meat intake to poultry meat, as in scenario S2, and further emission reduction to 44% if substituting legumes as in scenario S3. Tables VII-VIII show the age- and sex-specific meat, fruit and vegetable intakes adjustments in scenario S1, S2, and S3, respectively. As anticipated, most of the emission reduction is attributable to lower red meat intake among 20 year to 49 year old males. The emission difference between the import and global context indicates that relying totally on either imported or domestic food supplies may not be as carbon efficient as a right combination of domestic productions and imports.

TABLE II
ESTIMATED PERCENTAGE CHANGE IN GHG EMISSION HONG KONG COUNTERFACTUAL SCENARIOS VS. BASELINE MEAT, FRUIT, VEGETABLE AND LEGUME INTAKES, BY 2030

			Male				Female				
		Units	PoM	RM	TM	PC	PoM	RM	TM	PC	TPC
	Baselines emissions	tCO_2-e /day	1071	11204	12274		1030	7934	8964		
Scenario S1	ΔVol	%	-63	-36	-44	72	-1	-11	-8	14	45
	Δ E1	%	-63	-38	-40	-32	-1	-8	-7	-3	-20
	Δ E2	%	-64	-30	-33	-28	-1	-7	-6	-5	-18
	Δ E3	%	-64	-30	-33	-27	-1	-7	-6	-4	-18
Scenario S2	ΔVol	%	14	-72	-47	93	150	-55	13	18	58
	Δ E1	%	14	-69	-62	-52	150	-43	-21	-19	-38
	Δ E2	%	14	-55	-49	-43	153	-36	-15	-14	-31
	Δ E3	%	14	-56	-49	-42	152	-37	-15	-14	-30
Scenario S3	ΔVol	%	-63	-72	-70	114	-1	-55	-37	33	76
	Δ E1	%	-63	-69	-69	-54	-1	-43	-38	-29	-44
	Δ E2	%	-64	-55	-56	-48	-1	-36	-32	-29	-40
	Δ E3	%	-64	-56	-56	-47	-1	-37	-33	-27	-38

ΔVol: intake volume changes, Δ E1: emission change based on imported food emission factors; Δ E2: emission change based on global domestic emission factors; Δ E3: emission change based on global domestic and imported food combined emission factors, PoM: Poultry meat, RM: red meat, TM: total meat, PC population change vs. baseline total meat intake. TPC: Total aged 20+ population change vs. total baseline meat intake.

C. Baseline Burden of Diseases and Counterfactual Scenario Outcomes

Male adults had significant higher crude rate of diseases than did females in 2013 and 2014, respectively (Table IX). The models estimated 2,519-7,012 premature deaths in adult males and 53-1,350 premature deaths in adult females could be prevented by adjusting Hong Kong population meat intakes in line with AGHE-2011-MS recommendations as in scenarios S1 and S3, respectively (Table III). Seventeen burdens, especially those associated with all-cause, CVD, and cancer mortalities; and CHD, stroke, diabetes and lung cancer incidences could be reduced in all scenarios and especially among males. Although there are significantly higher percentage reductions in burden of diseases among younger adult aged 20 years to 59 years old, significant higher incidence reductions would be seen among adults aged 40+ years old and especially among those aged 70+ years old. Most reduction would be seen among males, but very little reduction among females excepting for all-cause and CVD mortalities and stroke incidences among females 70+ years old in scenarios S2 and S3, where three servings of red meat intakes per week were proposed instead of the 0.7 serving per day. Sensitivity analyses also showed consistent results.

D. Comparing Against Studies of Australian Populations

Compared to studies of Australian populations [9], Hong Kong adults have higher per capita meat supply for consumption but lower actual meat intakes among adults. However, it is unclear if this is because Hong Kong adults may have a relatively higher level of underestimation of their actual meat intakes, higher level of edible meat wasted, and/or Hong Kong young people aged 19 years and under may have higher level of meat intake. Higher proportions of meat intakes in Hong Kong are from processed and red meat, mainly pork instead of high carbon emission bovine meat. Hong Kong adults also have significant higher per capita fish and seafood intakes, 71 g/capita/day in Hong Kong vs. 30g/capita/day in Australia. Meat intakes in Hong Kong are also highly disproportionate but with different intake distributions by age groups (Table X). Red meat intake among Hong Kong males aged 20 years to 49 years old are significantly higher than among Australian males of the same ages, whereas in those aged 50+ years, it is slightly lower. Red meat intakes among Hong Kong females are consistent with those in Australia, except among those aged 70+ years old, among whom, it is significant less than it is among similarly aged Australian females. Adjusting red meat intakes to recommendations as stated in scenarios S1, S2 and S3 could bring significantly higher proportion reduction in burden of diseases in Australia than in Hong Kong (Table IV). In addition to the effects of differences in meat intake patterns and disease patterns, differences in population distributions also contribute to the outcome differences. Differences in other dietary factors such fish and seafood product intakes, smoking and physical activity patterns, as well as other risk factors such as air pollution, UV intensity between these two

geographic locations also affect disease patterns.

IV. Discussions

The estimated GHG emission and health outcomes of reducing Hong Kong adult population meat intakes are consistent with results from other co-benefit studies [18], as well as estimations of the similar counterfactual adjustments made in Australia [8], [9], and that all scenarios reduce GHG emissions and burden of diseases. When compared with study [9], this study showed even in high meat intake populations, different geographic regions may have different population structures and meat intake patterns not only by age and by sex but also by meat types. As a result, different intervention foci and strategies are needed, and consequently, variation in intervention leverages and outcomes should be expected. Therefore, regional specific investigations and evaluations are recommended for better quality policy-making. The three counterfactual scenarios intervention leverage ranges covered not only the Australian government recommendations, but also the Hong Kong government, the WCRFI, the Dietary Guidelines for Americans, and the UK Eatwell Plate recommendations [11]-[13], and hence provide great dietary flexibility to accommodate diverse individual and social preferences.

TABLE III
Estimated Changes in Hong Kong Burden of Disease Incidences by 2030 by Scenarios

Scenarios	S1	S2	S3	S1	S2	S3	Scenarios	S1	S2	S3	S1	S2	S3
	Male			Female				Male			Female		
All-causes mortality#1	-2519	-4853	-7012	-52	-1199	-1350	Endometrial cancer risk						
CVD mortality#1	-703	-1456	-1854	-11	-329	-346	Oesophagus#2	-45	-104	-104	-2	-13	-13
Cancer mortality#2	-284	-838	-838	-25	-253	-253	Lung cancer#2	-424	-1021	-1134	-22	-233	-233
CHD#1*	-1942	-1964	-3243	-70	-47	-147	Pancreatic cancer#2	-5	-5	-5	-1	-1	-1
Stroke#1*	-1498	-2106	-3234	-74	-379	-508	Breast cancer#2	-1	-1	-1	-12	-119	-119
Diabetes II#1*	-428	-340	-946	-38	-3	-115	Non-Hodgkin lymphoma#2	-35	-36	-88	-6	-2	-15
Colorectal cancer#2	-38	-38	-38	-8	-8	-8							
Colon#2	-68	-196	-196	-2	-75	-75							
Stomach#2	-33	-97	-97	-5	-28	-28							

#1: 2014 crude rate per 100,000 persons from Hospital Authority: Department of Health
#2: 2013 incidence crude rate per 100,000 persons from Hospital Authority: Hong Kong Cancer Registry web site [17] (accessed January 2016)
*Rate of inpatient discharges and deaths.

TABLE IV
Estimated Percentage Change in Burden of Diseases by Scenarios by 2030, Hong Kong vs. Australia

Percentage change in number	S1 vs #S1		S2 vs #S5		S3 vs #P1		S1 vs #S1		S2 vs #S5		S3 vs #P1	
	HK	AUS	HK	AUS	HK	AUS	HK	AUS	HK	AUS	HK	AUS
	Male						Female					
All-cause mortality	-6	-14	-11	-22	-15	-30	0	-3	-3	-9	-4	-18
CVD mortality	-7	-15	-14	-25	-18	-32	0	-4	-3	-11	-4	-19
Cancer mortality	-2	-3	-6	-6	-6	-7	0	-1	-3	-4	-3	-4
CHD	-6	-10	-6	-15	-10	-20	0	-3	0	-5	-1	-12
Stroke	-7	-20	-9	-28	-14	-40	0	-3	-2	-7	-2	-30
Diabetes II	-4	-7	-3	-11	-9	-15	0	-2	0	-5	-1	-9
Colorectal cancer	-1	-2	-1	-2	-1	-2	0	-1	0	-1	0	-1
Colon cancer	-2	-9	-7	-7	-7	-9	0	-2	-3	-4	-3	-5
Stomach cancer	-3	-6	-8	-10	-8	-11	-1	-3	-4	-6	-4	-7
Endometrial cancer							-4	-5	-10	-13	-9	-24
Esophageal cancer	-8	-11	-19	-19	-19	-21	-1	-5	-7	-11	-7	-13
Lung cancer	-8	-14	-20	-24	-22	-30	-1	-3	-8	-10	-8	-18
Pancreatic cancer	-1	-2	-1	-2	-1	-2	0	-1	0	-1	0	-1
Breast cancer	-2	-3	-5	-5	-5	-6	0	-1	-3	-3	-3	-3
Non-Hodgkin's lymphoma	-5	-5	-5	-12	-12	-14	-1	-3	0	-6	-3	-7
*1 Renal cell cancer	-7	-8	-9	-14	-11	-20	0	0	0	0	0	-11
*1 Hepatocellular Carcinoma	-5	-5	-8	-13	-12	-15	-2	-3	-1	-7	-5	-7

HK: Hong Kong, AUS: Australia, #: Corresponding scenarios in [9],
*1: combined change in relative risks.

V. Limitations

Both GHG emission and health outcome evaluation models are subject to model, emission factors, and relative risks input data limitations which have been extensively described in [8] and [9]. Meat intake data were mainly estimated from data set under the 'meat', 'burgers' and 'Dim sum' data files obtained from the Hong Kong Food and Environmental Hygiene Department. As meats in burgers and dim sum were not included in the "meat" file, estimates of meat in burgers and dim sum were subject to the limitations of estimations

obtained from the government Food Nutrient Calculator [19] and online recipes. Meat in sandwiches, bread, biscuits, egg rolls and similar foods may not be included. Although most of food products are imported and mainly from China, not all food products are imported. Meat, fruit and vegetable intakes were taken in 2005-2007, while diseases patterns were taken from 2013-2014. Although, evidence from a population survey in Australia showed that meat intakes in 1996 and 2011 were more or less the same, dietary intakes patterns in 2013-2014 in Hong Kong could be different from those in 2005-2007. It is reasonable to assume PAF per 100,000 persons for dietary intakes remain unchanged, as in 2013-2014, if keeping the intake levels at 2013-2014 unchanged, PAF in 2005-2007 could be different. However, the data used in this are the best data that could be obtained.

VI. Conclusion

Meat intakes among Hong Kong adult males are significantly higher than recommended. Whereas meat, and especially red meat intakes among males are significantly higher than those in females across all adult age groups, so are burden of diseases. Adjusting meat intakes to government recommended healthy levels could contribute significantly to both reduced GHG emission and burden of diseases. Significant more intervention effort is needed to reduce red meat intakes among males and especially among those aged 20 years to 59 years old.

Appendices

TABLE V
Mean Food Cradle to Ready to Eat at Home/Restaurant Emission Factors (GCO^2-E/G) [5]

	Imported Food#1	Global Domestic production#2	Global#3
Bovine meat	90.25	64.40	65.44
Ovine meat	55.20	65.74	62.90
Pig meat	17.08	16.19	16.20
Chicken meat	8.78	8.93	8.92
Fruit	1.54	0.92	1.18
Vegetable	2.19	1.55	1.72
Legumes	3.27	1.27	1.86
Raw Sugarcane sugar		1.07	

#1. Import context assumed effects of all food intake changes takes place through import. As Australia is one of the bovine meat exporter, no change in bovine or ovine meat import to Australia were expected even in the import context. Import emission factors were used for all other food intake changes.

#2. Global domestic context evaluated global domestic effects. It assumed reduction or increase in food intake in one region direct affects food production in other regions. Global domestic emission factors were used of for all food intake changes.

#3. Global context evaluated global effects as whole. Pooled global domestic production and import (including import transportation and process) emission factors were used for all food intake changes.

TABLE VI
Meat, Fruit and Vegetable Intakes Dose Responses Used in the Disease Burden Evaluations [2]

Disease	Food types	Unit (g/day)	Relative risk (CI: 95%)	Low	High	Sources
All causes mortality	Processed meat	50	1.15	1.11	1.19	[20]
	Total red	65	1.11	1.09	1.13	[20]
	Fruit	75	0.94	0.91	0.98	[21]
	Vegetable	75	0.95	0.92	0.99	[21]
CVD mortality	Processed meat	50	1.24	1.09	1.40	[22]
	Fresh red, men	65	1.16	1.05	1.28	[22]
	Fresh red, women	65	1.13	1.08	1.19	[22]
	FV	75	0.95	0.92	0.98	[21]
	Vegetable	75	0.96	0.93	0.99	[21]
Cancer mortality	Processed meat	50	1.08	1.06	1.11	[20]
	Total red	65	1.08	1.06	1.09	[20]
CHD risk	Processed meat	50	1.42	1.07	1.89	[23]
	Fruit	75	0.96	0.93	0.98	[24]
	Vegetable	75	0.96	0.94	0.98	[24]
Stroke risk	Processed meat	50	1.14	1.05	1.25	[25]
	Fresh red meat	65	1.05	1.01	1.10	[25]
	Fruit	75	0.87	0.80	0.93	[26]
	Vegetable	75	0.96	0.92	0.99	[26]
Diabetes II risk	Total meat	65	1.10	1.04	1.15	[27]
Colorectal cancer risk	Processed meat	50	1.18	1.10	1.28	[28]
Colon cancer risk	Processed meat	50	1.17	1.08	1.28	[28]
	Total red	65	1.09	1.01	1.17	[28]
Stomach cancer	Processed meat	50	1.71	1.34	2.19	[29]
	Total red	65	1.11	1.03	1.20	[30]
Endometrial cancer risk	Total meat	65	1.22	1.01	1.46	[31]
Esophageal cancer risk	Processed red meat	50	1.81	1.32	2.48	[32]
	Fresh red	65	1.25	1.10	1.41	[32]
Lung cancer risk	Total red	65	1.27	1.15	1.39	[33]
	FV	75	0.97	0.93	1.00	[34]
Pancreatic cancer risk	Processed meat	50	1.19	1.04	1.36	[35]
Breast cancer risk	Processed meat	50	1.09	1.03	1.16	[36]
	Total red	65	1.06	1.03	1.08	[36]
Non-Hodgkin's lymphoma risk	Vegetable	75	0.92	0.88	0.96	[37]
Renal cell cancer risk	FV	75	0.97	0.95	0.99	[38]
	Fruit	75	0.96	0.93	0.98	[38]
Hepatocellular Carcinoma risk	Vegetable	75	0.94	0.91	0.97	[39]

TABLE VII
PERCENTAGE CHANGES IN HONG KONG MEAT, FRUIT, AND VEGETABLE INTAKES SCENARIOS S1, (% /CAPITA/DAY), BY 2030

Age Group (years)	20-29	30-39	40-49	50-59	60-69	70+	Total change
				Male			
Bovine meat	-62	-61	-46	-38	-12	0	-40
Ovine meat	0	0	0	0	0	0	0
Pig meat	-38	-41	-43	-36	-28	-23	-34
Poultry meat	-83	-80	-78	-73	-32	-5	-63
Red meats	-46	-48	-43	-36	-24	-18	-36
Total Meat and alternatives	-59	-58	-54	-47	-26	-15	-44
Fruit	307	207	96	71	0	0	69
Vegetable	20	31	25	0	0	0	9
Legumes	502	382	441	378	380	202	361
Population change	110	110	96	74	19	12	72
				Female			
Bovine meat	-11	-6	0	0	0	0	-4
Ovine meat	0	0	0	0	0	0	0
Pig meat	-1	-12	0	-40	-26	0	-13
Poultry meat	-58	-55	-32	-12	96	191	-1
Red meats	-4	-11	0	-31	-21	0	-11
Total Meat and alternatives	-25	-27	-12	-25	9	49	-8
Fruit	0	0	0	0	0	0	0
Vegetable	0	0	0	0	0	0	0
Legumes	469	329	113	310	0	0	177
Population change	16	17	7	20	5	19	14
Total population change	69	62	54	49	13	15	45

TABLE VIII
PERCENTAGE CHANGES IN HONG KONG MEAT, FRUIT, AND VEGETABLE INTAKES SCENARIOS S2, (% /CAPITA/DAY), BY 2030

Age Group (years)	20-29	30-39	40-49	50-59	60-69	70+	Total change
				Male			
Bovine meat	-79	-79	-71	-68	-56	-44	-68
Ovine meat	0	0	0	0	0	0	0
Pig meat	-78	-78	-79	-75	-71	-71	-75
Poultry meat	-62	-53	-30	10	134	178	14
Red meats	-77	-78	-76	-73	-67	-65	-72
Total Meat and alternatives	-72	-70	-61	-48	-18	-7	-47
Fruit	307	207	96	82	0	0	71
Vegetable	99	94	61	1	0	0	27
Legumes	502	382	441	378	335	159	343
Population change	149	147	123	87	22	14	93
				Female			
Bovine meat	-55	-51	-37	-33	-11	80	-31
Ovine meat	0	0	0	0	0	0	0
Pig meat	-61	-66	-64	-65	-61	-54	-62
Poultry meat	46	57	96	135	328	475	150
Red meats	-59	-62	-57	-58	-52	-39	-55
Total Meat and alternatives	-18	-19	-3	4	45	95	13
Fruit	0	0	0	0	0	0	0
Vegetable	0	0	0	0	0	0	0
Legumes	407	289	76	17	0	0	111
Population change	18	20	9	6	20	39	18
Total population change	92	81	70	49	21	25	58

TABLE IX
PERCENTAGE CHANGES IN HONG KONG MEAT, FRUIT, AND VEGETABLE INTAKES SCENARIOS S3, (% /CAPITA/DAY), BY 2030

Age Group (years)	20-29	30-39	40-49	50-59	60-69	70+	Total change
				Male			
Bovine meat	-79	-79	-71	-68	-56	-44	-68
Ovine meat	0	0	0	0	0	0	0
Pig meat	-78	-78	-79	-75	-71	-71	-75
Poultry meat	-83	-80	-78	-73	-32	-5	-63
Red meats	-77	-78	-76	-73	-67	-65	-72
Total Meat and alternatives	-79	-78	-76	-73	-59	-51	-70
Fruit	307	207	96	82	17	-10	71
Vegetable	114	110	82	26	0	0	38
Legumes	601	476	607	592	770	739	641
Population change	158	159	143	120	59	33	114
				Female			
Bovine meat	-55	-51	-37	-33	-11	80	-31
Ovine meat	0	0	0	0	0	0	0
Pig meat	-61	-66	-64	-65	-61	-54	-62
Poultry meat	-58	-55	-32	-12	96	191	-1
Red meats	-59	-62	-57	-58	-52	-39	-55
Total Meat and alternatives	-59	-59	-48	-43	-14	21	-37
Fruit	0	0	0	0	0	0	0
Vegetable	0	0	0	0	0	0	0
Legumes	1151	772	521	537	165	0	472
Population change	43	44	37	35	17	10	33
Total population change	108	99	93	80	40	24	76

TABLE X
HONG KONG BASELINE BURDEN OF DISEASES CRUDE RATE PER 100,000 PEOPLE 2013/2014

Age groups	20-29	30-39	40-49	50-59	60-69	70+	20+		20-29	30-39	40-49	50-59	60-69	70+	20+
				Male								Female			
All-causes mortality#1	36	83	183	423	1233	5184	1566	All-causes mortality#1	15	36	87	221	576	3945	981
CVD mortality#1	3	14	46	96	272	1162	350	CVD mortality#1	1	4	11	28	106	1041	243
Cancer mortality#2	8	17	60	199	575	1386	476	Cancer mortality#2	3	13	57	142	304	819	255
CHD#1*	7	67	449	1003	1817	2506	1159	CHD#1*	2	7	44	188	692	1632	492
Stroke#1*	15	41	177	382	993	2140	782	Stroke#1*	13	31	94	209	520	1838	526
Diabetes II#1*	12	38	112	233	518	905	369	Diabetes II#1*	9	19	46	127	381	962	295
Colorectal cancer#2	3	8	32	91	248	380	155	Colorectal cancer#2	1	5	21	59	140	264	92
Colon#2	2	3	17	44	143	252	96	Colon#2	0	3	12	39	98	187	64
Stomach#2	0	1	5	17	57	110	40	Stomach#2	0	2	5	15	29	53	19
Oesophagus#2	0	0	3	12	34	43	19	Oesophagus#2	0	0	0	2	6	16	5
Lung cancer#2	1	4	21	77	268	485	179	Lung cancer#2	0	4	16	48	108	212	73
Pancreatic cancer#2	0	1	4	11	36	42	19	Pancreatic cancer#2	0	1	1	7	27	39	14
Breast cancer#2	0	0	0	1	1	2	1	Breast cancer#2	4	37	136	175	169	148	116
Non-Hodgkin lymphoma#2	2	3	10	19	42	57	26	Non-Hodgkin lymphoma#2	2	4	5	14	16	35	14

#1: 2014 crude rate per 100,000 persons from Hospital Authority: Department of Health
#2: 2013 Incidence rate per 100,000 persons from Hospital Authority: Hong Kong Cancer Registry web site [17] (accessed January 2016).
* Rate of inpatient discharges and deaths

TABLE XI
COMPARISON OF HONG KONG VS. AUSTRALIA MEAT INTAKE GAPS VS. RECOMMENDATIONS IN AGHE-2011-MS AND PRE-2011 AGHE, SERVING/CAPITA/DAY

Age Group (years)	Hong Kong	20-29	30-39	40-49	50-59	60-69	70+
	Australia	19-30	31-50		51-70		71+
				Male			
		Intake differences vs. AGHE-2011-MS					
Red meat	Hong Kong	**0.8**	**0.9**	**0.8**	0.6	0.3	0.2
	Australia	0.4	0.6		0.7		0.3
Meat and alternatives, minus red meat	Hong Kong	**1.1**	**1.0**	**0.8**	0.5	0.1	0.0
	Australia	0.9	0.5		0.3		0.1
Total difference	Hong Kong	**1.9**	**1.9**	**1.5**	1.1	0.4	0.2
	Australia	1.3	1.1		1.0		0.4
		Intake differences vs. Pre-2011 AGHE					
Meat and alternatives	Hong Kong	**3.1**	**3.0**	**2.6**	2.2	1.5	1.3
	Australia	2.5	2.3		2.3		1.6
				Female			
		Intake differences vs. AGHE-2011-MS					
Red meat	Hong Kong	0.0	0.1	0.0	0.3	0.2	0.0
	Australia	-0.1	0.0		0.4		0.4
Meat and alternatives, minus red meat	Hong Kong	0.3	0.3	0.1	0.0	-0.2	-0.4
	Australia	0.0	0.2		0.1		0.0
Total difference	Hong Kong	0.4	0.4	0.1	0.4	0.0	-0.4
	Australia	0.0	0.2		0.5		0.3
		Intake differences vs. Pre-2011 AGHE					
Meat and alternatives	Hong Kong	1.4	1.5	1.2	1.1	0.7	0.4
	Australia	1.1	1.4		1.4		1.1

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